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CABLE-MAKING FOR SUSPENSION BRIDGES AS EXEMPLIFIED IN THE EAST RIVER BRIDGE.

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II.

4. *The Guidewire.*—The guidewire serves as a guide, parallel to which the single wires of a strand are suspended and adjusted. This is the work of a few minutes, while the regulation of the guidewire requires days and sometimes weeks; but once adjusted it guides all wires in the cable. With the commencement of every new strand it is lengthened an inch or two as a precautionary measure to assure sufficient lengths for the former. For too short a strand there is no remedy, while one longer than necessary is easily shortened in the manner already described.

The cable, which at first hangs parallel with the guidewire, occupies in the finished bridge a considerably lower position, caused by the weight of superstructure, etc. This last position must be determined before hand, and in the case of the East River Bridge depends upon the following considerations:

The law demands that the lowest point of the bridge in the center of the river shall in no case be less than 135 feet above mean high water. An indiscriminate raising of the cable however, would not only increase its tension, but also the grade of floor which already amounts to 3¼ feet in 100′.

The latter difficulty might be overcome by lengthening the suspenders, but this again deprives the bridge of the advantage, obtained by short suspenders, viz., a rigid connection between cable and floor in the center of the span which prevents oscillations.

It follows, therefore, that a strict adherence to the maximum deflection is imperative. This deflection in the finished bridge will be 124.74 feet below saddle plates or 127.64 feet below the point of intersection of the two tangent lines, drawn common to cable and saddle in river and land span. Let us now examine the influences acting on the cable, which tend to change its elevation. They are of various kinds:

1. The weight of superstructure produces an elongation of the wires and hence a sinking of the curve throughout its length.

2. The diagonal stays, relieve the cable in the quarters next to the towers partially of its load, effecting a rise at these places and a depression of the central portion.

3. The inclination of the resultant of pressure towards the river causes a motion of saddles in the same direction, until equilibrium is established between the horizontal tensions of river and land cables. This will produce a further sinking of the cable in the middle span, and a rise in the side spans.

4. The cables are manufactured in a vertical plane, but afterwards they are drawn in an inclined position which causes the vertex of the center curve to rise again.

5. The changes in temperature cause the cable alternately to rise and fall.

Concerning the first point: *Elongation of Wires.*—Extensive tests have been made in regard to the stretch under a certain load. The modulus of elasticity averaged 29000000 which corresponds to an elongation of $\frac{1}{14500}$ of its length per net ton of strain per square inch of section:

2. *Effect of Stays.*—The usual method of calculating the strength of stays consists in attributing a certain equally distributed load to them, and in computing each single one according to the proportionate part of the load, and the angle which its direction forms with the stay. This of course gives only an approximate assurance that the stays really support all the weight allotted to them, and in consequence of this uncertainty some engineers have condemned altogether their application. They, however, neglect the consideration that the principal object of stays is not their supporting power, but the stiffness which they give to the floor. Except by such means, this same stiffness can only be attained by high and heavy trusses, which, though very effective, are considerably more expensive, besides adding greater weight and cost to the cables. For large bridges, therefore, stays are a matter of economy.

The following investigation will show what effect the stays, if supporting a certain load, have on the shape of the cable. Forcing the cable to take the calculated shape, actually will at the same time force the stays to support the assumed load; or reversedly from the shape of the cable the tension of each stay can be computed. Therefore the first objection to the application of stays becomes futile. But there exists a second and more serious one, namely, that in different temperatures they do not work in unison with the cable. This objection is justified in a great measure, and various devices have been proposed to overcome the difficulty. E. W. Serrell (see Report of Board of Consulting Engineers of New York and Long Island Bridge, Feb., 1877) proposes to suspend a lever from the saddles over the tower, and to attach the stays to a series of pivots placed on the line of this lever, so arranged that its movements compensate for the different contractions and expansions of chain and stays. Charles Bender proposes to make suspender and stay in one piece, passing around a roller under the floorbeam. This arrangement is beyond doubt effective. Perhaps an advantageous modification of it might be, instead of making suspender and stay continuous, to attach them separately to a lever turning on a pivot, the arms of which could be so calculated as to confer on stay and suspender its due proportion of load.

The trusses of the East River Bridge are provided with expansion joints at the end of the stay systems, and the resultant motion of floorbeams compensates for elongations and contractions in stays and cable. This, however, is, in the present case, more a fortunate combination of circumstances than an inherent consequence of the arrangement. In all similar cases, it is therefore advisable to examine the movement of certain points of connection of suspender stay and floorbeam, under different temperatures. The point being common to the three parts, its final position must be the result of the motion of each single part. If not, the former equilibrium of forces is disturbed, and one or the other part is overstrained, or performs no work.

3. *Motion of Saddles.*—This takes place theoretically when the horizontal tension of the cable on one side of tower exceeds that on the other. But the friction of rollers counteracts this motion.

All formulas on rolling friction, as given in books, are based upon the supposition that it stands in direct proportion to radius of rollers and to the pressure. But this does not agree with

actual experiments, on which alone a certain reliance can be placed. In general, our knowledge of rolling friction is small, and therefore, calculations based on it are more or less liable to errors.

W. Nordling (Mémoire sur les Piles en Charpente Métallique des grand Viaducs), experimenting with rollers of ten centimeters diameter, found the friction for a pressure of 1,000 kilo. to be 3½ kilo. The result of a few experiments made by the author was 4.6 lbs. for 1,000 lbs. with 2 inch rollers and 5 lbs. with 1 inch rollers. Very thorough and valuable experiments were made by Shaler Smith on the friction of drawbridges, (see transactions of the American Society of Civil Engineers, August, 1874). He experimented with eleven different drawbridges, with each from 25 to 70 times, and found as average from six bridges with rollers of 2 feet 8 inches diameter, the friction to be 6.7 lbs. for 1,000 lbs. pressure, and 7.5 lbs. as average of five bridges with rollers of 1′ 6″ diameter. The rollers under the saddles of the East River Bridge are 3½ inches in diameter; the weight upon each saddle is about 1,250 tons. Comparing this case with Shaler Smith's experiments, and assuming that the friction will increase for smaller rollers in the ratio as he found, the friction will be 9½ to 10 lbs. per 1,000 lbs.

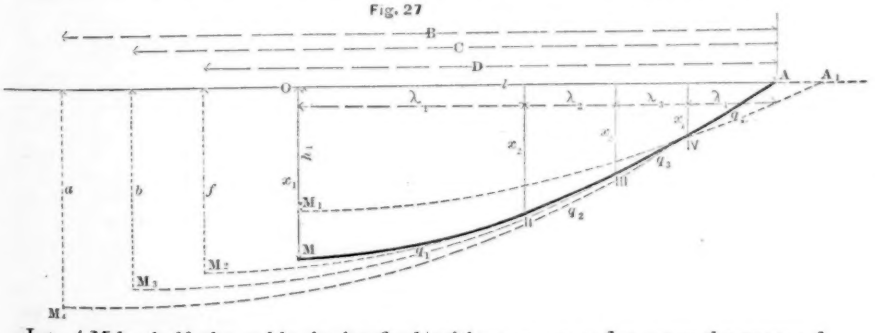
4. *Cradling of Cables.*—Changing the position of cables from a vertical to an inclined plane will produce a negative factor in the causes for depression.

In other words, it will raise the vertex of outer cables 0.455 feet, and that of the inner 0.163 feet. Hence, the cables can be hung this much lower, and the above given deflection of 127.64 can be increased to 128.095 feet.

5. *Changes of Temperature.*—A difference of three degrees Fahrenheit causes the vertex of river cable to rise or to fall one inch. In the following calculation no reference will be taken of changes produced by heat and cold; it is sufficient to carry it out for a certain fixed temperature, and we assume the given deflection to take place at ninety degrees Fahrenheit. Afterwards the guidewire can be corrected according to the temperature of the day in which it is regulated.

The circumstance, that the motion of saddles is not known before hand, or in other words, that the relative span of middle and land cable is not defined, makes a general solution of the problem impossible. But under certain suppositions, the correctness of which afterwards must be proved, we can proceed in two ways. Either we guess the position of guidewire and see whether under all the different influences it will reach a final deflection of 128.095 feet—or else we assume the final position of saddles and work backward, calculating the rise of the cable which would take place if the superstructure were removed. The assumed position of saddles must afterwards be verified, which generally will require two or three trials and repetitions of the calculation. We proceed after the second method and consider therefore the following problem:

Fig. 27



Let AM be half the cable in its final position of the span $2l$ and deflection x_1 loaded symmetrically per lineal foot with q_1, q_2, q_3 and q_4 over the spaces λ_1, λ_2, λ_3 and λ_4. The load q_1 represents the weight of superstructure per lineal foot;

q_2, q_3 and q_4, the same, less supporting power of stays within the spaces $\lambda_2 \lambda_3 \lambda_4$. This supporting power is greatest near the tower and diminishes towards the outer stays on account of their greater length and smaller angle. For the sake of simplicity we assume only three variations and consider the load between two points equally distributed. Properly it changes from stay to stay, but the variation is so small that practically it produces no effect and would only make the formulas unnecessarily lengthy and inconvenient.

Under this supposition each piece between points I and II, II and III, etc., is part of a parabola which, if prolonged, will have its vertex in M, M_2, M_3 and M_4, corresponding to the spans l, D, C and B and the deflections x_1, f, b and a. Calling the ordinates of points M, I, II, III and IV in regard to a horizontal line through A: x_1, x_2, x_3, x_4 and the length of curve AM : S, we shall have to determine the following ten unknown parts: S, x_2, x_3, x_4, B, C, D, a, b, f, and need therefore ten equations. The whole system is a suspended polygon in equilibrium, the single parts of it consisting of segments of parabolas. Expressing the length of the whole curve in the adopted symbols will give the first equation. Three more will be obtained in expressing the condition that points II, III and IV are points of certain parabolas. The horizontal force in each suspended polygon is equal throughout; this will give three other equations. Finally we receive three conditions in expressing that the tangents to points II, III and IV are each common to two parabolas. The length of curve AM is given in the following formula:

$$S = B\left\{1+\tfrac{2}{3}\left(\frac{a}{B}\right)^2-\tfrac{2}{5}\left(\frac{a}{B}\right)^4\right\}-(B-\lambda_4)\left\{1+\tfrac{2}{3}\left(\frac{a-x_4}{B-\lambda_4}\right)^2-\tfrac{2}{5}\left(\frac{a-x_4}{B-\lambda_4}\right)^4\right\}$$

$$+(C-\lambda_4)\left\{1+\tfrac{2}{3}\left(\frac{b-x_4}{C-\lambda_4}\right)^2-\tfrac{2}{5}\left(\frac{b-x_4}{C-\lambda_4}\right)^4\right\}$$

$$-(C-\lambda_4-\lambda_3)\left\{1+\tfrac{2}{3}\left(\frac{b-x_3}{C-\lambda_4-\lambda_3}\right)^2-\tfrac{2}{5}\left(\frac{b-x_3}{C-\lambda_4-\lambda_3}\right)^4\right\}$$

$$+(D-\lambda_4-\lambda_3)\left\{1+\tfrac{2}{3}\left(\frac{f-x_3}{D-\lambda_4-\lambda_3}\right)^2-\tfrac{2}{5}\left(\frac{f-x_3}{D-\lambda_4-\lambda_3}\right)^4\right\}$$

$$-(D-\lambda_4-\lambda_3-\lambda_2)\left\{1+\tfrac{2}{3}\left(\frac{f-x_2}{D-\lambda_4-\lambda_3-\lambda_2}\right)^2-\tfrac{2}{5}\left(\frac{f-x_2}{D-\lambda_4-\lambda_3-\lambda_2}\right)^4\right\}$$

$$+\lambda_1\left\{1+\tfrac{2}{3}\left(\frac{x_1-x_2}{\lambda_1}\right)^2-\tfrac{2}{5}\left(\frac{x_1-x_2}{\lambda_1}\right)^4\right\} \quad (1)$$

Condition, that points A and IV are points of the same parabola:

$$\frac{B^2}{a}=\frac{(B-\lambda_4)^2}{a-x_4} \quad . \quad . \quad . \quad (2)$$

The same conditions for points III and II:

$$\frac{(C-\lambda_4)^2}{b-x_4}=\frac{(C-\lambda_4-\lambda_3)^2}{b-x_3} \quad . \quad (3)$$

$$\frac{(D-\lambda_4-\lambda_3)^2}{f-x_3}=\frac{(D-\lambda_4-\lambda_3-\lambda_2)^2}{f-x_2} \quad . \quad (4)$$

Equality of the horizontal force gives the following:

$$\frac{q_4 B^2}{2a}=\frac{q_3 (C-\lambda_4)^2}{2(b-x_4)} \quad . \quad . \quad . \quad (5)$$

$$\frac{q_4 B^2}{2a}=\frac{q_2 (D-\lambda_4-\lambda_3)^2}{2 (f-x_3)} \quad . \quad (6)$$

$$\frac{q_4 B^2}{2a}=\frac{q_1 \lambda_1^2}{2 (x_1-x_2)} \quad . \quad . \quad . \quad (7)$$

Tangent in point II is common to parabolas $\overline{MII}$ and $\overline{II\,III}$:

$$\frac{\lambda_1}{x_1-x_2}=\frac{D-\lambda_4-\lambda_3-\lambda_2}{f-x_2} \quad . \quad (8)$$

The same condition for points III and IV:

$$\frac{D-\lambda_4-\lambda_3}{f-x_3}=\frac{C-\lambda_4-\lambda_3}{b-x_3} \quad . \quad . \quad (9)$$

$$\frac{C-\lambda_4}{b-x_4}=\frac{B-\lambda_4}{a-x_4} \quad . \quad . \quad . \quad (10)$$

The solution of these ten equations seems at first laborious, but can be simplified much by introducing the following six new equations:

$$\left.\begin{aligned}
&\frac{(B-\lambda_4)^2}{B^2}=n\\
&\frac{q_1}{q_4}\frac{\lambda_1^2}{B^2}=m\\
&\frac{q_2}{q_4}\frac{(C-\lambda_4)^2}{B^2}=p\\
&\frac{q_3}{q_4}\frac{(D-\lambda_4-\lambda_3)^2}{B^2}=r\\
&\frac{(D-\lambda_3-\lambda_2-\lambda_3)^2}{(D-\lambda_4-\lambda_3)^2}=s\\
&\frac{(C-\lambda_4-\lambda_3)^2}{(C-\lambda_4)^2}=t
\end{aligned}\right\}\quad(11)$$

From these follows:

$$\left.\begin{aligned}
a-x_1&=na & x_1-x_2&=ma\\
b-x_4&=pa & f-x_3&=ra\\
f-x_2&=rsa & b-x_3&=tpa
\end{aligned}\right\}\quad(12)$$

Substituting equations (12) in (1) the latter obtains the form:

$$\begin{aligned}
&\frac{a^2}{B}-\tfrac{3}{5}\frac{a^4}{B^3}-\frac{n^2a^2}{B-\lambda_4}+\tfrac{3}{5}\frac{n^4a^4}{(B-\lambda_4)^3}+\frac{p^2a^2}{C-\lambda_4}\\
&-\tfrac{3}{5}\frac{p^4a^4}{(C-\lambda_4)^3}-\frac{t^2p^2a^2}{(C-\lambda_4-\lambda_2)^2}\\
&\quad+\tfrac{3}{5}\frac{r^2a^2}{(D-\lambda_4-\lambda_3)}-\tfrac{3}{5}\frac{r^4a^4}{(D-\lambda_4-\lambda_3)^3}\\
&-\frac{r^2s^2a^2}{(D-\lambda_4-\lambda_3-\lambda_2)}+\tfrac{3}{5}\frac{r^4s^4a^4}{(D-\lambda_4-\lambda_3-\lambda_2)^3}\\
&\quad+\frac{m^2a^2}{\lambda_1}-\tfrac{3}{5}\frac{m^4a^4}{\lambda_1^3}\\
&\quad=\tfrac{3}{5}(S-l)\quad.\quad.\quad.\quad.\quad(1a)
\end{aligned}$$

Calling now:

$$\begin{aligned}
&\tfrac{3}{5}\Big\{-\frac{1}{B^3}+\frac{n^4}{(B-\lambda_4)^3}-\frac{p^4}{(C-\lambda_4)^3}\\
&\quad=\frac{t^4p^4}{(C-\lambda_4-\lambda_2)^3}-\frac{r^4}{(D-\lambda_4-\lambda_3)^3}\\
&+\frac{r^4s^4}{(D-\lambda_4-\lambda_3-\lambda_2)^3}-\frac{m^4}{\lambda_1^3}\Big\}=v\quad.\quad(13)
\end{aligned}$$

And:

$$\begin{aligned}
&\Big\{\frac{1}{B}-\frac{n^2}{B-\lambda_4}+\frac{p^2}{C-\lambda_4}-\frac{t^2p^2}{(C-\lambda_4-\lambda_2)}\\
&\quad+\frac{r^2}{(D-\lambda_4-\lambda_3)}-\frac{r^2s^2}{(D-\lambda_4-\lambda_3-\lambda_2)}\\
&\quad+\frac{m^2}{\lambda_1}\Big\}=u\quad.\quad.\quad.\quad.\quad(14)
\end{aligned}$$

And substituting these values in (1*a*) we arrive at:

$$a^4+a^2\frac{u}{v}=\frac{3}{2v}(S-l)\qquad\text{or:}$$

$$a=\sqrt{-\frac{u}{2v}\pm\sqrt{\frac{3}{2v}(S-l)+\left(\frac{u}{2v}\right)^2}}\quad(15)$$

A combination of equations (2), (3) to (10) results in:

$$\left.\begin{aligned}
D&=\frac{q_1}{q_2}\lambda_1+\lambda_2+\lambda_3+\lambda_4\\
C&=\frac{q_1}{q_3}\lambda_1+\frac{q_2}{q_3}\lambda_2+\lambda_3+\lambda_4\\
B&=\frac{q_1}{q_4}\lambda_1+\frac{q_2}{q_4}\lambda_2+\frac{q_3}{q_4}\lambda_3+\lambda_4
\end{aligned}\right\}\quad(16)$$

If these values of D, C and B are substituted in equations (11) we find n, m, p, v, s and t, and consequently we have in (12) six simple equations for determining the last six unknown parts. These are: b, f, x_2, x_3, x_4 and a or x_1, according on which preliminary supposition the calculation was based. If originally the deflection of the guide wire was assumed, we know the length S and find (a) from equation (15) then (16) gives the unknown deflection x_1. If, on the other hand, x_1 is known at the beginning, we find (a) from equation (16), and S by substituting its value in (1*a*).

The numerical values in the present case are: $l=799.55'$, $\lambda_1=399.77'$ $\lambda_2=\lambda_3=\lambda_4=133.26'$; $q_1=1212$ lbs. $q_2=1024$ lbs. $q_3=762$ lbs. $q_4=180$ lbs. $x_1=128.095$.

The span $2l$ is equal to the distance between centers of towers plus the distances between these and points of intersection. By the trigonometrical survey the former was found to be 1595.5 feet, and two careful measurements made across the footbridge by two different methods gave for the same distance 1595.3 and 1595.4 feet proving the correctness of each result. In this calculation the figure of 1595.4 was taken as the mean value. The total load to be supported by stays will be 222500 lbs. divided so, that the first set between points A and IV supports 137500 lbs., the second 60,000 and the third 25,000 lbs. These weights deducted from the total weight and reduced to the lineal foot give the above values for $q_1\ q_2\ q_3\ q_4$.

By substituting these values in equation (1) we find:

$$S=812.467'.$$

Now suppose all weight be removed, then the saddle will move from A to A_1, point M will rise to M_1, and the dotted

curve $A_1 M_1$ (see Fig. 27) will be the position of the guidewire. In order to find its deflection h_1 we must know the length of $A_1 M_1$. This is equal to AM less the contraction caused by removing from the cable all load, and consequently all tension.

At point A the tension is a maximum, expressed through:

$$q_1 \frac{B}{2a}\sqrt{B^2+4a^2}=2892000 \text{ lbs.}$$

and at M a minimum:

$$\frac{q_1 \lambda_1^2}{2(x_1-x_2)} = 2794080 \text{ lbs.}$$

The average between these two and the tension in points *I*, *II*, and *IV*, is:

2849451 lbs. = 1424.72 tons.

If q_1 was uniformly distributed over the whole cable, that is, if no stays would help in the support of the load, the deflection x_1 would be 125 feet and the maximum tension at A would be 3237858 lbs.

This compared with the greatest tension above reveals the curious fact, that, while the stays support $\frac{3}{9}$ths, of the total load, the tension in cable is decreased only $\frac{2}{17}$ths.

Calling L the length of cable $A_1 M_1$, w its area in square inches, T the average tension, in tons, of cable AM, we find L by the formula:

$$L+\frac{L\,T}{14500-w}=812.467$$

$T=1424.72$ tons $w=133.928$ □″

hence $L=811.871$

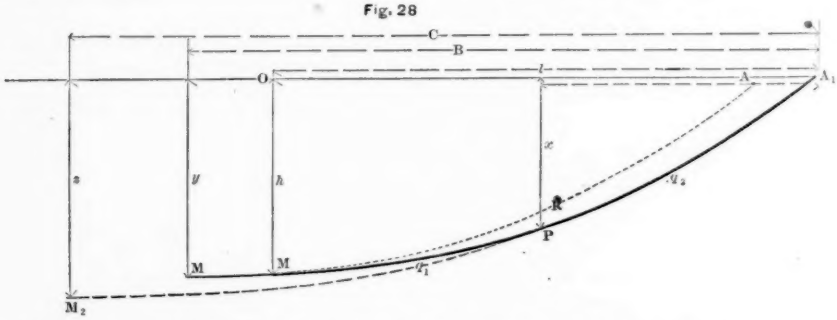
If $A_1 O$, the span of guidewire, be called l_1 we finally find its deflection h_1, through the relation:

$$l_1\left\{1+\tfrac{8}{3}\left(\frac{l_1}{h_1}\right)^2-\tfrac{32}{5}\left(\frac{l_1}{h_1}\right)^4\right\}=L$$

$$h_1=\sqrt{\tfrac{5}{6}l_1^2\pm\sqrt{\tfrac{5}{2}l_1^4\left(1-\frac{L}{l_1}\right)+(\tfrac{5}{6}l_1^2)^2}}$$

The distance AA_1 we supposed to be equal to 0.1 foot, hence $l_1=799.55+0.1=799.65$ and $h_1=121.926$, which determines the deflection of the guidewire in case the assumption of the distance AA_1, will prove correct. This will be the case if with due regard to the friction of rollers, the horizontal tensions of river and land cables are alike. To determine the latter, a calculation similar to the one for middle cable, must be made; but it will be sufficient to consider the load supported by stays as equally distributed. Though this assumption will make a noted difference in the shape of curve, it will change the amount of horizontal tension so little as to be of no practical value, while on the other hand, it will much simplify the formulas. Considering the uncertainty in rolling friction, it is altogether not necessary to be too exact in this calculation.

Fig. 28



In the diagram above, the curve $A\,R\,M$ indicates the land cable, which was adjusted to balance the middle cable before being loaded. If now the weights q_1 and q_2 are suspended from it, A will move to A_1 and the curve will take the position $A_1\,P\,M$, M being a fixed point. Our task is to find a relation between the abscissas and ordinates of the new curve, which will enable the determination of the horizontal tension. The average tension in curve $A_1\,P\,M$ must be equal to the average tension of middle cable, and as we know the length

ARM, we also know the length $A_1 PM$. If M_1 and M_2 are the lowest points of the two parabolas MP and PA_1 the above length is also expressed by the equation:

$$S = C\left\{1+\tfrac{2}{3}\left(\frac{z}{C}\right)^2\right\} - (C-\lambda)\left\{1+\tfrac{2}{3}\left(\frac{z-x}{C-\lambda}\right)^2\right\}$$
$$+(B-\lambda)\left\{1+\tfrac{2}{3}\left(\frac{y-x}{B-\lambda}\right)^2\right\} - (B-l)\left\{1+\tfrac{2}{3}\left(\frac{y-h}{B-l}\right)^2\right\}$$

or:

$$\frac{z^2}{C} - \frac{(z-x)^2}{C-\lambda} + \frac{(y-x)^2}{B-\lambda} - \frac{(y-h)^2}{B-l} = \tfrac{3}{2}(S-l) \qquad (1)$$

In this equation the higher powers of the fractions $\frac{z}{C}$, etc., which are very small, were neglected, as greater accuracy is not necessary. The horizontal forces at A_1 and P must be equal,

$$\frac{q_2\, C^2}{z} = q_1 \frac{(B-\lambda)^2}{y-x} \quad . \quad . \quad (2)$$

In point P both parabolas MP and PA_1 have a common tangent,

$$\frac{C-\lambda}{z-x} = \frac{B-\lambda}{y-x} \quad . \quad . \quad . \quad (3)$$

To these three equations must be added those of the two parabolas of which the whole curve is composed:

$$\frac{(B-\lambda)^2}{(B-l)^2} = \frac{y-x}{y-h} \quad . \quad . \quad . \quad (4)$$

$$\frac{C^2}{(C-\lambda)^2} = \frac{z}{z-x} \quad . \quad . \quad (5)$$

With these five equations we can determine the five unknown parts B, C, x, y and z.

From (5) and (2) follows:

$$z-x = \frac{z}{C^2}(C-\lambda)^2 \quad . \quad . \quad (6)$$

$$y-x = \frac{q_1}{q_2}\frac{z}{C^2}(B-\lambda)^2 \quad . \quad . \quad (7)$$

and from a combination of (7) with (4):

$$y-h = \frac{q_1}{q_2}\frac{z}{C^2}B-l)^2 \quad . \quad . \quad (8)$$

A result of these last equations is:

$$\left.\begin{aligned} B &= \frac{q_2}{q_1}(C-\lambda)+\lambda \\ y &= \frac{z}{C^2}(C-\lambda)(B-C)+z \\ x &= z-\frac{z}{C^2}(C-\lambda)^2 \end{aligned}\right\} \qquad (9)$$

$$z = \frac{C^2 h}{2\,l\,C - 2\,l\,\lambda - \frac{q_1}{q_2}(l-\lambda)^2+\lambda} \qquad (10)$$

Substituting the values of $z-x$, $y-x$, $y-h$ and B in equation (1) and calling $\frac{3}{2}(s-l)=m$ we arrive after proper reductions, at:

$$z^2\left\{3\,l\,C^2 + C\left[(l-\lambda)^2\left(3-3\frac{q_1}{q_2}\right)-3l^2\right]\right.$$
$$+\lambda^2\left(3\frac{q_1}{q_2}-2\right)+\lambda^2 l\left(3-6\frac{q_1}{q_2}\right)+3\frac{q_1}{q_2}l^2\lambda$$
$$\left.+\left(\frac{q_1}{q_2}\right)^2(l-\lambda)^3\right\} = m\,C^4 \quad . \quad . \quad (11)$$

Several expressions in (11) and (10) are constant, and we set, therefore, as an abbreviation:

$$\left(l-\lambda\right)^2\left(3-3\frac{q_1}{q_2}\right)-3\,l^2 = N$$

$$\lambda^2\left(3\frac{q_1}{q_2}-2\right)+\lambda^2 l\left(3-6\frac{q_1}{q_2}\right)$$
$$+3\frac{q_1}{q_2}l^2\lambda+\left(\frac{q_1}{q_2}\right)^2(l-\lambda)^3 = R$$

$$2l\lambda - \frac{q_1}{q_2}(l-\lambda)^2-\lambda^2 = p.$$

Substituting the value of z in (11), the latter obtains the form:

$$3\,l\,C^2 + CN = \frac{m}{h^2}(4l^2C^2-4lCp+p^2)-R$$

from which follows:

$$C = -\frac{N+\frac{4m}{h^2}lp}{6l-\frac{8m}{h^2}l^2}$$
$$\pm\sqrt{\frac{\frac{mp^2}{h^2}-R}{3l-\frac{4m}{h^2}l^2}+\left\{\frac{N+\frac{4m}{h^2}lp}{6l-\frac{8m}{h^2}l^2}\right\}^2}$$

The value of C once known it is easy by means of equations (9) and (10) to find B, x, y and z.

The numerical values of the constant parts are in our case:

$$l=952.65',\ h=188.3'$$

$q_1=1212$ lbs. $q_2=748$ lbs. $\lambda=400'$

which give the following results:

$$C=1282.8\ \ z=222.1,$$

hence horizontal tension:

$$H=q_2\frac{C^2}{2z}=2770592 \text{ lbs.}$$

This is 23488 lbs. less than the one in middle span; but the weight on one saddle is 1250 tons (the total superstructure weighing about 5,000 tons), therefore if equilibrium consists between the two spans, the friction for 1,000 lbs. must be:

$$\frac{23488}{2500}=9.4 \text{ lbs.}$$

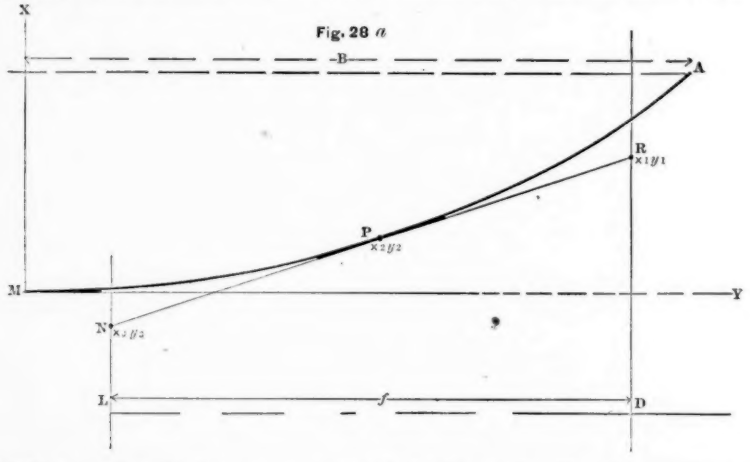
This is the same as was found to correspond with the experiments, and, therefore, our supposition, that each saddle moves 0.1′ towards the river, can be considered as correct and also the calculated deflection of guidewire.

In regulating the guidewires for the East River Bridge, it was at first thought sufficient to adjust only the center span, and to rely upon the force of gravity to establish a balancing curve in each land span. But the result showed, that, though the wires were supported on small rollers, the friction was too great to allow a free rendering. A separate adjustment for each span was therefore deemed necessary.

Two guideboards placed on the same level were fastened across the archways in both towers and a level instrument, on a scaffold behind, was so adjusted, that the cross line in the telescope coincided with the upper edges of both boards, while the telescope itself was level. With this arrangement it was possible to sight all four wires from the same position, because a turn of the telescope would not change the height of sight line.

The guideboards were moveable in an iron frame in order to adjust their height according to the temperature. A similar arrangement served for the land spans. A board was fastened to the masonry of each tower forty feet below saddleplate. A tangent line from the upper edge of this board drawn to the land curve, will intersect the face of anchorage at a certain height, which, determined by calculation, will serve to establish a sight line for the regulation.

Fig. 28 *a*



APM (see Fig. 28*a*) represents the curve of land cable, *NR* the tangent in point *P*, *NL* the face of anchorage and *RD* that of tower. Taking *M* (the vertex of the curve) as origin of coordinates, *My* as axis of ordinates and *MX* as axis of abscissas and calling the coordinates of *R*, *P* and *N*: x_1y_1, x_2y_2 and x_3y_3 we have first the two linear equations:

$$y_1=ax_1+b$$

$$y_2=ax_2+b$$

from which follows :

$$y_1-y_2=a(x_1-x_2) \qquad (1)$$

x_2y_2 being also a point in the parabola, we have the relation :

$$y_2^2=2px_2- \qquad (2)$$

and taking the differential of x_2 :

$$\frac{dy_2}{dx_2}=2p$$

$$\frac{dy_2}{dx_2}=\frac{p}{y_2}$$

This is the equation for the tangent to point P; but (a) also denotes this tangent in equation (1), hence we have $a=\frac{p}{y_2}$ and (1) obtains the form :

$$y_1-y_2=\frac{p}{y_2}(x_1-x_2)$$

$$y_2=\frac{2px_2}{y_1}+\frac{p}{y_1}(x_1-x_2)$$

The position of point R being a fixed one, its coordinates are equal to constants and we can set :

$$y_1=c \quad x_1=d$$

hence

$$y_2=\frac{2px_2}{c}+\frac{p}{c}(d-x_2)$$

$$y_2^2=\frac{p^2}{c^2}(d^2+2dx_2+x_2)$$

or

$$2px_2=\frac{p^2}{c^2}d^2+\frac{p^2}{c^2}2dx_2+\frac{p^2}{c^2}x_2^2$$

$$x_2=\frac{c^2}{p}-d\pm\sqrt{-d^2+(\frac{c^2}{p}-d)^2}$$

in which $$p=\frac{B^2}{2h}$$

x_2 being known, the value of y_2 is found through equation (2) and x_3 by the relation : $y_1-y_3=a(x_1-x_3)$ or as $y_1-y_2=f$:

$$x_3=\frac{ad-f}{a}$$

A successful regulation can only be accomplished in perfectly calm weather, and it requires therefore careful watching for sometimes several weeks until a favorable day offers itself. This was the case at the East River Bridge, where for three weeks all attempts of regulating were fruitless. As even a light breeze suffices to displace considerably a wire of such a length, and as the utmost exactness is imperative, the importance of an opportune day is evident. The wires used for guidewires were carefully selected from rings of equal weight per foot. It was necessary to examine about fifty rings in order to find three of equal weight. This shows the importance of the precaution. The regulating commenced on the New York land span and proceeded from there to middle, and, lastly, to the Brooklyn land span. Afterwards the wires were let free and found to be in perfect balance. In other less important cases, where a difference in deflection of a foot or eighteen inches is of no consequence, the calculation may be simplified by neglecting the higher powers of small fractions. Guessing, however, at the effects of stays according to existing bridges may be simple and may apparently also result in a strong and substantial bridge, but, nevertheless, should not be recommended, because it deprives the engineer of the opportunity to calculate exactly the tensions in the different parts of his bridge, the ignorance of which may, if not fatal to the bridge, prove at least a loss of safety or of capital.

VITALITY IN ARCHITECTURE.

From "The Architect."

If the proverb be true—and few will be disposed to deny it—that a live dog is better than a dead lion, it must surely be of the utmost importance in all enterprises of artistic composition, amongst other things, that they be living and not lifeless. In a general way almost everybody who looks at a picture or a statue in the Royal Academy halls is able to recognize vitality; in a building, although not after the same manner, the intelligent observer may none the less clearly perceive the presence of a spirit of design which is quite entitled to be called

life, and perhaps in contrast, not far off, another spirit, or want of spirit, which it is no mistake to identify with deadness of soul.

Some authorities affirm that in this singular century of ours architecture is all dead. Chaos, they will go so far as to say, is what prevails, and nothing else. We have no architecture of our own. There is no such thing in being as nineteenth century style. A facade might just as well be on paper as on an edifice; indeed a great deal better if the producer of it on the paper has at his finger tips the vitality of touch which makes a good drawing. To copy is the order of the day. One copies from old Italy, another from old Greece, another from old France or Germany, another perhaps from old England; but everybody copies from somewhere a long way off and something probably long since obsolete. If anyone attempts a device by his own inspiration, he is found to have no inspiration of his own at command, and consequently his efforts end in affectation and delusion, in the creation of all kinds of dead devices and not living. As an especially notable case in point, there is, for example, the Queen Anne mode of architecture now in vogue, a more particularly lifeless affair than almost anything else that has ever been tried except perhaps the style of the Pavilion of King George IV. at Brighton.

But apart from the deadness of our architecture in the mass, it is suggested that our architects in detail are a whole class of very deadly-lively people. Now and then, and here and there, an individual artist makes his appearance with a manifestation in youth of something like vigor; but you have only to wait a little and you find that this is galvanic and not vital. He promises great things. He discountenances his brethren as weak vessels. He arms himself in the newly exhumed harness of some forgotten time or place, and is a nine days' wonder because he is actually a novelty. But when novelty wears off he has after all no more life in him than other people. The entire field of our current architectural art is a valley of dry bones, they say.

All this is obviously very discouraging. The enemies of the architect—and everybody in this world must have his enemies—take up their song against him with infinite gusto when argument of this kind comes on the carpet. His friends are nonplussed. He himself holds his peace for sheer weariness. For indeed the case is so easily made out against him that he knows not what to do to defend himself.

How is it possible, then—and the question has been frequently asked—to breathe into the nostrils of architecture and of architects a little of the breath of life? In other words, in what direction may we look for the chance of being able to commence a new era of design, accepting the principle, as we should certainly have to do, that it must begin at the beginning and probably at a very small beginning? All we want, let it be said, is vitality, but pray let us have that. However rough it may be, however timid it may be, let it be but life and not deadness, and when once started it will go.

Leaving out of account for the moment ecclesiastical architecture, and reserving the question whether it possesses, any more than secular, real vitality rather than galvanic, let us look at the secular alone as that in which the cry for life is most urgent. The prospect is certainly not a cheerful one.

A few years ago the hope of English architecture lay in the endeavor to devise some form or forms of Secular Gothic which should combine the conveniences of modern building with the authentic features and details of mediæval art. On the face of it this was an enterprise which might safely be said not to promise much. The so-called poetic quaintnesses which make up almost the whole character of genuine Gothic, non-ecclesiastical work in France, Germany, or Belgium, must manifestly accord so doubtfully with those prosaic arrangements, as we call them, which constitute the modern essentials, that there would be more than a probability of the prosaic in this case as effectually overwhelming the poetic as in most other cases it does when urged on by essentials to compete with non-essentials. Not only so, but our very modes of construction were quite opposed to the character of mediæval secularity, and, however closely we imitate the masonry, carpentry, ironwork or whatever else of the thirteenth

and fourteenth centuries, we soon found that it was only an imitation at the best and not a reality. On the whole, we presume the idea of building Gothic warehouses, banks, and offices, is in London abandoned altogether, and probably in the great provincial cities also, while the town halls alone may for some time longer be made subjects of experiment on the ground that municipality, like ecclesiasticism, has its traditions rooted in the Middle Ages. At any rate it is difficult to point to more than one or two examples of our recent Secular Gothic which are found to command general approbation now; and it is not at all unlikely that even these exceptions, which prove the rule of failure, will in course of a little further time fall into rank with the rest. All this, then, may probably be acknowledged to constitute by no means a successful endeavor to vivify English Architecture. No doubt the Gothic style was both forcible and fashionable, but the force in this development of it was not vital, and the popularity was, as usual, but fleeting.

To go back from the present time just twenty years, some of our readers may remember better than others the very peculiar position in which the genius of architecture was placed by its professors in the great double competition for the Government Offices at Whitehall which was held in 1857. No particular style of design was dictated in that instance, and the architectural world was engaged in the Battle of the Styles in a way which, for such a world, was more earnest than usual. There were to be some twelve or fourteen premiums awarded in the two divisions of the contest, and the judges were what is called a mixed commission, composed of one antiquary, one painter, one engineer, one amateur, and so on, and, as a particular favor, one architect. Half the number of designs in each division, speaking roughly, were Classic, and half Gothic. The course adopted by the mixed commission was eminently characteristic of such a body, and as devoid of vitality as any such thing could be. The best of the designs were simply placed in alternation of style, and the premiums awarded to Classic-Gothic-Classic-Gothic, if we are not mistaken, with the amiable regularity of a see-saw. The absurdity of the idea was apparent enough, but the state of criticism was such that the "impartiality" of the decision was universally applauded, and Lord Stanhope, Mr. Brunel, Mr. David Roberts, Mr. Burn, and their two or three colleagues of the same stamp, were considered indeed to have done a remarkably smart thing. It was perhaps a still more admirable result, as the outcome of the whole transaction, when Sir Gilbert Scott, after many years of controversy, was appointed to be architect of the edifice, on the humorous ground, as stated in Parliament in the interest of Secular Gothic by the ingenious Mr. Beresford Hope, that he had stood second in each division of the competition, and was therefore in a manner ahead of both the men who were first in only one. Lord Palmerston, equally ingenious, remarked that it was the first time he had ever heard the doctrine that the horse which ran always second was entitled to the stakes; but his lordship enjoyed at least this satisfaction in the end—that he was able to compel the architect to abandon his beloved Gothic and build in something like the rival manner.

Secular Gothic, nevertheless, has triumphed since then, and has had a very fair innings. It is now succeeded by the Queen Anne style. Having regard therefore to the demand for vitality, what is this? As we have above hinted, it seem to have come in as dead as a door nail. If we had been writing a few years ago and had said as dead as a Dutch William, the phrase might have passed for a tolerably good architectural joke. The style of the Dutch William and that of Queen Anne are of coure in effect the same thing; the Dutch William, or, red brick house of the age of William the Third, being indeed no more than the advanced development of the mode of his predecessor. Compared with any tolerably well-dressed example of our Secular Gothic, we must really submit that the specimens we see around us of modern Queen Anne are as yet not one whit more spirited, but rather less; and, as every month we wait to see what is to come of the change, the question becomes more important whether any vitality at all is to be manifested in it.

If we are called upon to define this artistic vitality, we shall be quite safe in asserting, in the language of theology,

that the quality cannot be defined and needs no defining, just as some of the most physiological of our philosophers are quite unable to define the quality of life in nature at large, and are content to suggest that, as it cannot be allowed to be electricity, it is something for ever occult.

It is not necessarily originality, nor even novelty. Bold eccentricity is an imitation of it, but not the reality. Slap-dash recklessness is as wide of the mark as mere mechanical finish. Even the article of finesse may be but a dead trick; and it need scarcely be said that high education and superabundant knowledge are to all appearance more likely to result in polished inanity than in anything more hopeful. Some authorities consider that at any rate the most likely way to reach it is to cultivate an intelligent and thoughtful *brusquerie*, trusting that such a spirit, being undoubtedly vigorous, may eventually expand, or contract, into vitality. Nor does it seem desirable just now, as the world goes, to discourage this hope. Thought and freedom, with modesty, appear as likely to have good effect as anything could.

No doubt mediæval architecture displays a large amount of unmistakable vitality, and we are willing to maintain that its revival in our own day has been productive of not a little that looks very like genuine life, at least in the best church work. But we fear it cannot be said that in classic architecture even the French, with all their finesse, have reached the same point, while we ourselves are far behind. There are those who hint that it is reserved for the engineer to make the dry bones of classic architecture live, but there is at least no sign for the present how this is to be accomplished.

THE INITIAL STIFFNESS OF THE ST. LOUIS ARCH, ETC.

By HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

In a communication "Concerning the St. Louis Arch," published in the August number of this Magazine, C. Shaler Smith, C.E., has stated that in two particulars my recent discussion of that bridge was erroneous. This distinguished engineer has so complete an acquaintance with the theory and practice of bridge building, that his opinions upon these questions are of great weight; but as I am unable yet to agree with him respecting the points in dispute, I wish in few words to show the substantial truth of the opinions which he claims are erroneous.

In the first place, he asserts that the following statement is "erroneous in the highest degree:" "The St. Louis Arch is wanting in initial stiffness to such an extent, that the weight of a single person is sufficient to cause a considerable tremor over an entire span."

This statement was made to the writer by two credible and competent witnesses who had examined the bridge independently. Now, admitting for the moment that this is an exaggerated statement of the fact, I think we are entitled to assert that the Arch is deficient in initial stiffness, even from Mr. Smith's own testimony; for he states in the same paragraph, that "the maximum effect of all is produced by the passage of a coal wagon loaded to seven tons, jolting over the rough flooring." Now, this is less than two per cent. of the live load which the Arch is designed to sustain, and is a mere nothing compared with the enormous load which the bridge would sustain without injury. It is of no consequence whether the weight be seven tons or less, the fact that any such small weight produces a maximum effect of this kind shows the initial flexibility of the Arch. The cause of this flexibility appears to lie in the fact, that the points of zero bending moment are shifted back and forth for a great distance along the Arch by the jolting of the wagon; and it is not beyond belief that at certain

temperatures the same effect may be produced by the weight of a single person jumping up and down at the crown. When, however, a great weight moves upon the bridge, the bending moments immediately become more considerable, and the points of zero bending moment become more sharply defined by the comparatively large moments on either side of it; or, to describe the fact in graphical terms, when the bridge is not loaded, the curve of equilibrium approximates closely to the curve of the arch itself, and a slight additional weight moves their points of intersection long distances; but in case of a large eccentric load the curves diverge widely, and cut each other at a larger angle, while a small additional load changes the configuration very little. This initial flexibility appears to be the necessary condition of any stiff girder subjected to very small bending moments, and the case of the stiffening truss of an ordinary suspension bridge, mentioned by Mr. Smith, is exactly in point. The case of the Suspension Bridge, at Cincinnati, affords a curious confirmation of this theory. The vertical component of any tremor is propogated but a short distance along the bridge, owing to the frictional stiffness of the roadway and truss which quickly destroys waves of this kind, as was explained in my recent discussion of that bridge; but, on the contrary, the horizontal lateral component of the tremor due to jolting of passing loads is noticeable for considerable distances. The flooring and roadway, excepting when a strong wind is blowing against the bridge, are precisely in the condition just spoken of as favorable to the propogation of considerable tremors.

These results show the incorrectness of supposing that "theorizing on this special subject is useless," provided the theory and facts agree. In the second place, exception is taken to the following sentence of my article: "It is the conviction of the writer that the stiff arch rib adopted in the construction of the St. Louis Bridge was a costly mistake, and that, if a metal arch was desirable, a flexible arch rib with stiffening truss was far cheaper and in every way preferable." Now any bridge which costs so much that the income from it does not now, or cannot in the near future, yield a fair return on the capital invested, is "a costly mistake" in proportion to the magnitude of the investment. I am informed that the St. Louis Bridge, costing some twelve or thirteen millions of dollars, was a very bad investment of capital, and I suppose I share the information with a large constituency. I shall be glad to learn that I am mistaken, and that the bridge pays a fair per cent. upon its first cost. Were Chief Engineer Smith now called upon to design the bridge, he would, I have no doubt, recommend a truss instead of an arch, as the feasibility and cheapness of a 520 feet truss is proven by the design adopted for the 520 feet span of the Southern Railway Bridge, at Cincinnati. I had supposed, as above stated, that it was possible to build a flexible arch and straight truss more cheaply than a stiff arch. It seems from the admissions of Mr. Smith, that the cost of manufacturing the parts of the flexible arch is less than that of the braced arch, but that the cost of erecting the former is much the greater of the two, owing to the false works needed in the former case, and not needed in the latter. Now, no one is perhaps more fully informed than Mr. Smith, as to what it is possible to do in the way of erecting bridges without false works, and I should like to ask him if he is willing, in the light of what has now been accomplished in this particular, to adhere to the statement, that "a flexible arch could not" be erected, of the dimensions proposed, without false works. I have not found time to make the necessary computations, but it appears reasonable to suppose that the bracing between the arch and its stiffening truss could, at a very moderate expense, be designed to sustain the stresses it would be subjected to in case the arch were erected without false works.

In conclusion, the St. Louis Bridge is of an unusual type, and its construction was, in some respects, an experiment; it ought, therefore, to receive such discussion and criticism at the hands of those interested in bridges, as to settle as many disputed points as possible. If the bridge is wanting in initial stiffness, the engineering profession ought to be informed of the fact; and, if possible, the real reason of it, according to sound

theory, should be also pointed out, in order that the defect may be avoided in future. If the first cost of the bridge was excessive, that too is a mistake which may perhaps not be again committed, especially if it be shown that in spans of this length some other design presents fewer difficulties in an engineering point of view, and is less costly to execute.

THE MANUFACTURE OF GONGS.

By G. W. YAPP.

From "Journal of the Society of Arts."

The effect of hammering renders Chinese gongs extremely brittle, a sharp, sudden blow causing them to fly to pieces like glass. The Chinese, therefore, use them with great care near the outer edge, tapping them gently with a padded stick, and cause the vibrations to increase very gradually until their full sound is evolved. When by accident they are broken, the pieces are collected with great care for the fabrication of new gongs. These pieces are heated to a dull red, and when cooled are easily broken into fragments. The best of these are selected, and, being mixed with the metal scraped off the gongs in the manufacture, are melted in common crucibles like those used in England, each crucible containing 7 lbs. or 8 lbs. of the metal, in a special furnace which holds two crucibles. The fuel used is a kind of short-flamed coal, something like anthracite in appearance. The combustion is conducted with much care, the coal being placed around the crucibles by means of large tongs through a circular aperture in the furnace; and the heat is maintained by means of a simple blower, which consists of a long rectangular box with a wooden piston and clappers.

When the contents of a crucible are melted, the latter is taken from the furnace and weighed, and as soon as it is emptied it is refilled and replaced in the furnace. The temperature is very high, and it is in the upper part of the furnace that the broken metal is heated to redness, as already stated.

When melted, the metal is well stirred in the crucible before being turned out, the oxide and scum being at the same time carefully removed from the surface. It is then poured out into a mould, which consists of a disc of iron lying on a stone slab, and on which is placed a rim of clay to form the edge of the mould. The whole is then greased with oil obtained from oleaginous peas and sprinkled with fine sand; a conical cover of burnt clay is placed on the moist clay ring, and an orifice at the top of the cone is fitted with a funnel, through which the molten metal is poured. The object of all this arrangement is double; it prevents the metal cooling too rapidly in the mould, and it protects the workmen from the spitting of the metal. When the metal is set, but still red, the cover and the clay are removed, and the cake, which is less than half an inch thick, is well scrubbed with a sort of wooden brush on both sides to remove all impurities.

The first hammering is performed while the gong metal is still red, on a piece of cast iron about 6 inches high and 10 inches to twelve inches in diameter, and mounted on a block of wood. The disc is then beaten with a hammer which has a spherical head, and which, having a long and flexible bamboo handle, allows the workman to strike a hard but not dead blow. Two men are employed in this operation, one wielding the hammer and the other turning the metal disc in such a manner that it is gradually rendered concave. When this first hammering is finished, a disc of 14 inches diameter is raised to 2½ inches to 3 inches; the piece is then carried into another shop, where there is a furnace about 4 feet in diameter, heated with charcoal, and furnished, like the former, with a blowing-box. A skilled workman, who is seated by the furnace, removes the disc from the latter at the

critical moment to an anvil close at hand, and guides it while it is being hammered. On one side is a cistern of cold water, level with the floor of the shop, and on the other is a simple machine on which the disc is clipped round the edge by a cold chisel. While being heated, the workman turns the partly-formed gong round and round and over and over on the mass of incandescent charcoal, so that the metal may be heated thoroughly throughout; and when on the anvil—which, like the former, is a mass of cast iron—it is directed by the chief workman and beaten by five men with hammers and long handles. A peculiarity in the arrangement is that three of the men hammer continually in regular rotation, while the other two wield large hammers, but beat in unison with the rest. The ability and precision which these men show with their heavy hammers is said to be marvelous. The chief workman stops the operation when the sound of the metal tells him when it is getting cool, places it again in the furnace, and, when sufficiently heated, it is hammered a second time in the same manner. When this is done the gong is nearly of the proper form, and five or six in the same stage of fabrication are then heated together, and afterwards hammered together on the anvil. While this is being performed, all the five strikers aim at the same spot, the firemen turning and directing the work. By this system all the gongs are brought to the same shape and thickness one with the other. But the hammering is continued even after this, the two strikers exchanging their heavy hammers for wooden mallets with flat faces; this hammering is continued for a long time—three-quarters of an hour, says M. Champion, for gongs only 20 inches in diameter. Finally, the gongs are separated, and each one again hammered alone—principally, it would appear, in order to make any corrections in form—and the edges are carefully pared with a cold chisel. At this stage the gongs are very brittle, clippings being easily broken between the fingers; they are, therefore, heated to dull redness, and plunged for a few seconds in cold water, which is said not to contain any added substances to aid in the tempering.

The gongs are then taken into another shop, where they are scrubbed with a woollen rag and salt water; the water in evaporating leaves a small amount of salt on the metal, and the gong in this condition is again placed in the furnace, turned about in every direction, and again hammered. When the central portion of the gong is finished, the edges alone are heated, in order that any faults may be corrected. During these last operations, in order that the action of the fire may be more regular, and that no heat may be lost unnecessarily, a large sheet-iron cover, suspended to a bamboo handle, is held over the gong while in the fire, and is lifted from time to time to allow the firemen to see and turn the work.

Still the work is not yet completed: the edge of the gong has to be turned up to the proper angle, which operation is described as requiring the greatest ability in the workmen, for a single false blow would cause the metal to crack. The gong is now heated to redness for the last time, and thrown into cold water, where it is left for two or three minutes, when it is taken out and briskly rubbed with a wooden mallet to remove any oxide or foreign matter that may adhere to the surface. The final correction of the edge of the gong is effected by a workman who sits on the ground, and who uses two hammers with short handles, one to strike with and the other as an anvil. When he has completed his work, another man takes the gong, places it on an anvil about 8 inches square in the face, and with a round-faced hammer, weighing about 1 pound, with a short handle, passes over the surface, systematically commencing at the center and proceeding by concentric rings to the outer edge. Sometimes, however, the blows are given in the direction of the radii, but the reason of this is not explained. The blows are vigorous, but the wrist of the workmen must be elastic, as it were, so that the shock shall not last too long; but, with all possible care, the work sometimes fails at this point, and should a crack occur, which the workman knows immediately by the sound, the piece is thrown with the waste metal. The traces of this last series of blows are generally apparent in the finished gongs, although before leaving the factory they are scraped

with steel tools, either entirely or partially, the scraping being always effected from the center to the circle indicated.

The composition of these gongs has been found by the analysis of many specimens to be as follows:

Copper	82.00 parts.
Tin	17.00 "
Iron	1.00 "
Nickel	traces. "

The last-named metal can only be discovered by operating upon several grammes of the alloy.

In the manufactory inspected, the men were, on account of the excessive heat, working only during the night. They were paid fixed sums, and were bound to produce a certain number of gongs; the foreman who had the complete direction of the work received one piastre (about 4s. 6d.) per day, and the workman half that sum. The whole of them worked all but naked.

At Pekin and other places in the North of China, gongs may sometimes be seen a yard and even more in diameter; but these are rarely seen in the shops; they are said to be made in Cochin-China. A remarkably fine example was shown in the Japanese section of the Paris Exhibition of 1867; it was suspended, as usual, by means of silk-covered cords, and was struck by means of a piece of wood weighing probably 20 pounds, which was also suspended with one end opposite the center of the gong. The sound of this instrument was superb. The resonance of gongs varies materially, and the Chinese class their tones as male or female; those which have been subjected to the most careful and prolonged hammering produce the male tones.

M. Champion remarks that the Chinese gong-makers have a careless and apathetic air, but the skill, sureness of hand, and vigor which they exhibit in effecting the above long and tedious operations are surprising; their activity and energy is such that it is questionable whether any European workman could conduct such an operation successfully in the same time. The most celebrated place for the production of gongs is Su-tchou, a town remarkable for many manufactures.

The work is not carried on during the hottest months, on account of its laborious nature. The tam-tam is a necessary instrument at all marriages, funerals, public and religious fêtes, in short, in all ceremonies, and even on the occasion of visits of the superior mandarins; the demand for them is consequently enormous, and their production gives employment to a large number of men.

A DISCOVERY of mineral salt of much interest and importance has, says the London *Times*, recently been made at Aschersleben, in Prussia, in the vicinity of the Hartz Mountains. Within the last twenty years the Governments of Prussia and Anhalt have been deriving large profits from the working of sundry pits or mines productive of potash salts, situated at Stassfurth and Leopoldshall. Hitherto these undertakings have enjoyed a monopoly, but an independent party of explorers, aided by the diamond rock-boring apparatus, have succeeded in reaching the potash deposits at moderate depths not far from Stassfurth. The first boring reached what is called the "kainit" portion of the potash layer, which was proved to have a thickness of fifty English feet. As the Prussian mining law entitles the discoverers to a concession equal to an area of 2,189,000 square meters, it is computed that this discovery includes about 66,000,000 tons of potash salt.

But the explorers, consisting chiefly of English capitalists, have proceeded further, and by means of other borings have obtained the command of an enormous area of these valuable deposits, which are now going to be extensively worked. The discovery is likely to be of great service to chemical industry, by providing an ample supply of one of its staple commodities, the want of which threatened at one time to be rather serious. The extraordinary fertility imparted to the soil by the use of potash manure also renders the discovery a matter of direct interest to the agriculturist. Experience gained in Germany and Holland shows that by the use of the kainit and other forms of potash, land naturally poor can be made to bear extraordinary crops. This system of fertilization has been found peculiarly advantageous in the case of peat lands and moors.

PITCH OF RIVETS AND THICKNESS OF WEB IN RIVETED PLATE GIRDERS.

By THEODORE COOPER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE calculation of the sectional areas of the flanges of plate girders is readily performed, and generally correct; but when we examine the existing practice as to the pitch of rivets and thickness of webs employed, we find a wide variation. They are too often assumed by guessing or left to the option of the manufacturer. This must be due to a want of comprehension as to the laws governing these points. They are as readily calculated as any other proportions of the girders, governed, of course, as other parts are by our present knowledge of the resistance of the material under the kind of strain acting upon them.

We could prove our formulæ in a general manner, and then descend to particular examples, but we believe most practical men abhor analytical investigations, we will therefore prove our propositions for the commoner practical cases.

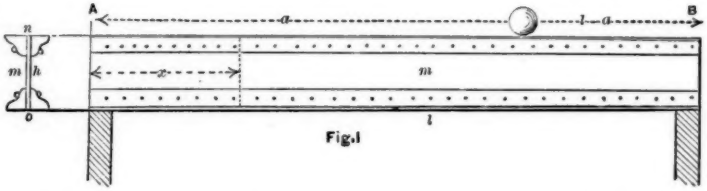


Fig. 1

1st. A simple girder supported at the two ends and carrying a single weight W at any point. The reaction at support A, or proportion of W delivered to that point equals $\frac{W(l-a)}{l}$ (1); The reaction at B $=\frac{Wa}{l}$ (2). The moment at any point x equals $M_x=\frac{W(l-a)x}{l}$ (3). The stress produced by this moment upon the flanges at x, is, $F_x=\frac{W(l-a)x}{lh}$ (4). That portion of the vertical force W which passes to the support A, or $\frac{W(l-a)}{l}$ is constant for all points between W and A, and is known as the *vertical shearing force* between these points. These are the well known formulæ as usually applied. We will now proceed to develop the stress coming upon the rivets connecting the web with the flanges n and o.

By examination of equation 4 we see that the flange strain varies for each value of x; being nothing at the supports, and increases regularly till it reaches a maximum value at the weight W. This increase in the stress is received from the web, and must be transferred by the rivets connecting the *web* with the *flanges*. The *number of rivets* therefore *between any two flange sections*, must be *sufficient* to *transfer this difference of stress*.

For any point x, $F_x=\frac{W(l-a)x}{lh}=\frac{Vx}{h}$ since V the vertical shearing force at this point, equals $\frac{W(l-a)}{l}$.

For any other point $x-\delta$ $F_{x-\delta}=\frac{V(x-)\delta}{h}$. The difference is the stress upon the rivets in the space δ (which we will call ω) or

$$\omega=\frac{Vx-V(x-\delta)}{h}=\frac{V\delta}{h}\quad(5)$$

Let δ = the distance between two consecutive rivets or the rivet pitch, then the stress upon any rivet equals the $\frac{\text{vertical shear}\times\text{the pitch}}{\text{depth of the girder}}$ or the pitch $\delta=\frac{\omega\times h}{V}$ (6), that is, the pitch required is

equal to the allowed stress upon one rivet multiplied by the depth of the girder, and divided by the vertical shear at the required point.

For this particular case, the depth and shear being constant, the pitch will be uniform from W to the supports, but different on opposite sides of the weight, unless the weight is at the center of the girder.

2d. A similar girder with a uniform load per foot of w.

Fig.2

The vertical shear at any point y, $V_y = wy$.

Flange strain at y, $Fy = \frac{W(c+y)(c-y)}{2h} = \frac{W(c^2-y^2)}{2h}$.

Flange strain at $y+\delta$, $F_{y+\delta} = \frac{w(c^2-(y+\delta)^2)}{2h}$

As before, the difference of these flange strains will be the stress upon the rivets in space δ,

$$\text{or } \omega = \frac{w}{2h}(c^2-y^2-c^2+y^2+2y\delta+\delta^2)$$

$$= \frac{w\delta}{h}\left(y+\frac{d}{2}\right) = \frac{V_{y+\frac{\delta}{2}}\,\delta}{h} \qquad (5)$$

which is identically the same as determined in previous case.

3d. A similar girder *fixed at both ends* and carrying a uniform load w.

The vertical shear at any point y, $V_y = w_y$

Flange strain at y, $F_y = \frac{w(c^2-y^2)}{2} - \frac{12}{32}wc^2$

Flange strain at $y+\delta$,

$$F_{y+\delta} = \frac{W(c^2-(y+\delta)^2)}{2} - \frac{12}{32}wc^2$$

Hence $\omega = \frac{V_{y+\frac{\delta}{2}}\,\delta}{h}$ as before.

We have restricted our investigation to parallel flanges for sake of simplicity, but the same results may be worked out for girders with inclined flanges.

What has been proved for stationary loads will equally apply to all cases of moving loads, the proper value for the vertical shear being determined for each special case.

For moving loads an additional fact must be borne in mind, that as a load passes from one end to the other of a girder the vertical shear is alternately negative and positive for each point, or in other words, the stress upon each rivet under a moving load is first towards one support, and then towards the other. Experiments show that when any piece is subjected alternately to strains in opposite directions, the total effect is more nearly the sum of the two, and for *rivets especially* the *sum* of the *two stresses* should be considered. This can readily be done by taking the sum of the vertical shears, as the total shear at any point. For example, a single concentrated weight W passing from one end to the other of a supported girder. The shear toward the support A is represented graphically by the triangle BA c, and towards the support B by the triangle ABd. The shear at each end being equal to W, and at the center to $+\frac{W}{2}$ and $-\frac{W}{2}$. By summing the two shears at all points we see it becomes equal to W. All the rivets, therefore, in such a girder should be proportioned for a stress equal to the whole weight.

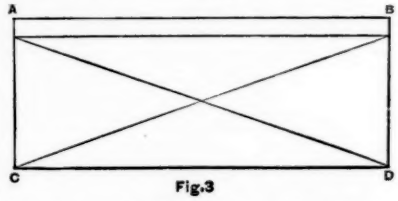


Fig.3

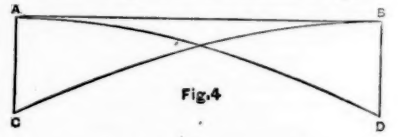


Fig.4

For a distributed load passing over a girder, the shear is represented by the two parabolas ABd and BAc. The shear

at each end being $\frac{Wl}{2}$ and at the center $\pm\frac{Wl}{8}$.

For such a girder it will be sufficient practically to proportion the rivets at the ends for a shear of $\frac{Wl}{2}$ and at the center for $\frac{Wl}{4}$, or *twice* the *pitch* at the *ends*. The intermediate ones proportionally. *Value of* ω. We have represented the stress transferred by each rivet by the symbol ω. This stress tends to shear the rivet, and also to elongate or tear out the rivet holes in the pieces connected by

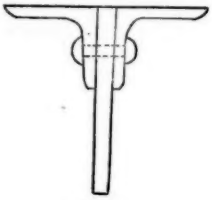


Fig. 5.

the rivet. (We shall not take into consideration the stress transferred by the friction due to the contraction of the rivet, as it is uncertain in amount and in duration), ω must then, in well proportioned girders, be less than or equal to the safe shearing resistance of the rivet. It must also be equal or less than the safe compressive resistance upon the area of the rivet hole in the thinnest member (web or flange) which is usually the web sheet.

We therefore have $\omega =$ or $<$

$$\begin{cases} 6{,}000 \text{ lbs.} \times \text{area of rivet (double or single shear)} \\ 12{,}000 \text{ lbs.} \times t \times d \end{cases} \qquad (7)$$

t = thickness of web in inches
d = diameter of rivet in inches

We have taken the allowed stress for shearing of rivets at 6,000 lbs., this being a fair value for iron which should have 10,000th safe strain under a tensile force, and 12,000 lbs. per $\square''$ as the safe compression upon the rivet hole, this being a proper value judging from the results obtained by the tearing action of pins in pin holes.

Whichever value of ω is the *least* of these two, must be used in each particular case.

ω for Shear of Rivets =

For 1″ Rivets.	Single Shear.	Double Shear.
$\frac{15}{16}$	4712 lbs.	9424
$\frac{7}{8}$	4142	8284
$\frac{13}{16}$	3608	7216
$\frac{3}{4}$	3111	6222
$\frac{11}{16}$	2751	5502
$\frac{5}{8}$	2227	4454
	1841	3682

ω for compression on rivet holes

Thickness of Web.	Diameter of Rivets.						
	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1″
$\frac{1}{4}$	1875	2063	2250	2434	2625	2812	3000
$\frac{5}{16}$	2344	2578	2812	3045	3281	3515	3750
$\frac{3}{8}$	2812	3093	3375	3656	3937	4218	4500
$\frac{7}{16}$	3281	3609	3937	4265	4593	4921	5250
$\frac{1}{2}$	3750	4126	4500	4868	5250	5624	6000
$\frac{9}{16}$	4218	4640	5062	5482	5906	6327	6750
$\frac{5}{8}$	4687	5156	5625	6094	6562	7030	7500
$\frac{11}{16}$	5156	5672	6188	6703	7219	7734	8250
$\frac{3}{4}$	5625	6188	6750	7312	7875	8437	9000

By substitution of the least value of ω for the particular thickness of web and diameter of rivet to be employed, in the formula (6).

$$\delta = \frac{\omega \times h}{V} \qquad (6)$$

taking the pitch and depth in the same unit of measure (inches preferably) we obtain the desired pitch.

THICKNESS OF WEB.

In formula (7) we see the influence of the thickness of the web, and from it can readily determine the *least* value allowed for such thickness. From (7) and (6) we get

$$t = \frac{\omega}{12000\,d} = \frac{V\delta}{12000\,dh} \qquad (8)$$

all dimensions in inches.

Practically the pitch of rivets (for a single row) should not be less than $4d$. Hence for the case of a *single row of rivets* $\delta = 4d$.

$$t = \frac{4Vd}{12000\,dh} = \frac{V}{3000\,h} \qquad (9)$$

(t and h in inches)

Formula 8 is *general* and *applicable* to all cases. Formula 9 will apply to the more *common cases* where the parts only allow of *one row of rivets*. These formulae give the varying thickness allowed in webs at different points of the girder by substituting the value of V, the vertical shear, at the required points.

Examples.—1st. A load W (stationary) =24000 lbs. at center of a girder with a

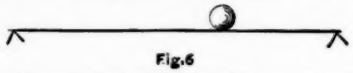


Fig.6

single row of rivets and pitch$=4d$, using (9) we get

$$\text{Thickness in inches} = \frac{4}{\text{Depth in inches.}}$$

2d. For the same load in motion

$$\text{Thickness in inches} = \frac{8}{\text{Depth in inches.}}$$

3d. For a uniform load Wl,

$V = \frac{Wl}{2}$ at the end of the girder and (9) becomes

$$t = \frac{Wl \text{ in feet}}{6000\ h \text{ in ins.}} = \frac{W}{72000}\frac{l}{d} \qquad (10)$$

(l and d being reduced to same unit)

By which we see that for the same unit of load, the thickness of the web depends upon the ratio $\frac{l}{d}$; or for the same ratio of $\frac{l}{d}$ the thickness depends upon the unit of load. We can therefore tabulate these results :

	W=1500	2000	2500	3000	3500	4000
$\frac{l}{d}=8$.....	$t=\frac{1}{6}''$	$\frac{2}{9}$	$\frac{5}{18}$	$\frac{1}{3}$	$\frac{7}{18}$	$\frac{4}{9}$
$=10$.....	$\frac{5}{24}''$	$\frac{5}{18}$	$\frac{1}{3}$	$\frac{5}{12}$	$\frac{1}{2}$	$\frac{5}{9}$
$=12$.....	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{5}{12}$	$\frac{1}{2}$	$\frac{7}{12}$	$\frac{2}{3}$
$=14$.....	$\frac{7}{24}$	$\frac{7}{18}$	$\frac{1}{2}$	$\frac{7}{12}$	$\frac{7}{10}$	$\frac{7}{9}$

For the lighter weights, it will be more economical to make the web of the same thickness throughout the girder, restricting the size to $\frac{1}{4}''$ as the thinest web to be used in any case.

For the heavier loads it will become a question of circumstances whether to make the web of one thickness for its whole length, or whether to reduce it towards the center and maintain the angles parallel by means of filling plates —or using wider angles, and increasing the frequency of the rivets by having more than one row of rivets.

The preceding investigation determines only the *minimum* value for the thickness of the web, necessary to resist the compressive strain brought upon it at the rivet holes, by the horizontal stress ω transferred to the flanges. In addition, the web must be able to resist the buckling tendency due to the vertical shear V at any point. We must therefore consider

THE WEB AS A COLUMN.

Let ABCD be a section of the web, AC being a section at any point and V the vertical shear at that point, ω is the horizontal stress for a length δ on the line AB, $\frac{\omega}{\delta}$ the same for a unit of length

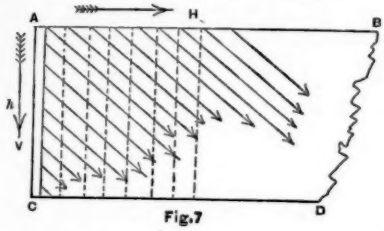


Fig.7

and $H=\frac{h\omega}{\delta}$, will be the amount of this stress for a distance h equal to the depth of the girder. But by equation (6) $\frac{h\omega}{\delta}=V$, whence we see that the horizontal and vertical shears are of equal intensity. We may therefore consider the vertical force acting upon any horizontal unit of the web to be the same as the portion of V acting upon a unit of the surface AC or $\frac{V}{th}$. From equation (9) $\frac{V}{th}=3000$ lbs. Therefore if our web has been determined by formula (9), we must find what depth of girder will safely resist as a column a strain of 3000 lbs. per □″. Using Gordon's formula with $\frac{1}{4}$ of ultimate as a safe strain, we have 3000 lbs. $=\frac{9000}{1+\frac{h^2}{3000t^2}}$, h being depth of girder and t thickness of web. Solving this we obtain $\frac{h}{t}=77$.

We may safely assume then that the web as determined by the formula (9) is able to resist buckling if the depth of the web does not exceed 80 times the thickness.

VERTICAL STIFFNESS.

When the depth of the web exceeds the above limit, it must either be made thicker, or else vertical stiffness must be added to resist the tendency to buckling.

It will also in all cases, be necessary to introduce vertical stiffness at the points of support, and beneath each concentrated load. They must be proportioned as columns and *must contain rivets enough* to transfer or receive the whole shearing force coming upon them, to or from the *web*.

A close fitting against the flanges alone will not be sufficient. This is self evident by an inspection of the forces shown in the section of the web in preceding paragraph.

WEB SPLICES.

When the web is formed of several pieces, these pieces must be spliced strongly enough to transfer all strains coming upon the web; which is V both in the vertical and horizontal directions, for a length of web equal to the depth of the girder. Therefore, the number of rivets on each side of a web, splice must be determined by the formula.

Number of rivets $=\frac{V}{\omega}$ taking the *least* value of ω from the preceding tables.

THE SEWAGE QUESTION.

By C. NORMAN BAZALGETTE, Barrister-at-Law.

From Proceedings of the Institution of Civil Engineers.

II.

A DIFFERENT tone distinguished the statements of the Commissioners in their second Report on the A B C process, dated the 4th of July, 1870, in which (p. 19) they say, "It is no doubt very desirable, in the interest of those towns where sewage cannot be dealt with by irrigation, that an experiment in intermittent downward filtration should be conducted on what may be considered a working scale, when all those difficulties would arise which do not show themselves in a laboratory experiment, and when it would be proved whether the process can be conducted on the drainage water of, say, 20,000 people, with the efficiency to which our laboratory experiments pointed, and without creating a nuisance."

The contrast between this hesitation of 1870 and the confidence of 1871 is

sufficiently striking. In 1870 there are difficulties to be considered which do not show themselves in a laboratory; but in 1871 "the laboratory experiments may be considered conclusive." In 1870 some doubt is expressed as to the possible efficiency of the process; but in 1871 it would require only 3 acres to permanently purify the sewage of a population of 10,000 inhabitants. An experiment upon a working scale was obtained at last at Merthyr Tydvil, under the auspices of Mr. Bailey Denton, M. Inst. C.E., and the Commissioners, in their fourth Report, 1872, were able to point to this practical proof of the accuracy of their theoretical conclusions. They say (p. 55) referring to the works at Merthyr, "they were designed by Mr. Denton expressly for the purpose of realising on a large scale the results of that process of intermittent filtration which had been devised and investigated in the laboratory of this Commission." And again (p. 56), referring to the dilution of the effluent by subsoil water, "Nevertheless, and even assuming a very high degree of purity for the subsoil water, the net result of the action of the soil of the intermittent filters upon the sewage was highly satisfactory, especially when it is considered that the sewage of a town of 50,000 inhabitants was thus purified on about 20 acres of land." And again (p. 102), "That intermittent filtration, conducted either on the extensive or intensive scale, is perfectly trustworthy for the abatement of the nuisance thus created, there is now ample testimony to prove." It thus stands upon record that at Merthyr the sewage of a population of 50,000 has been satisfactorily purified upon 20 acres of land, or in the proportion of 2,500 persons to an acre, and that the apprehension formerly expressed as to possible nuisance has been proved to be without foundation.

Never was there a more complete delusion. Never were exaggerated conclusions, based upon laboratory experiments, more completely confuted than by that very experience at Merthyr, which was quoted and relied upon as confirming their truth. Before proceeding to prove the facts incident to the first practical exposition of Downward Filtration at Merthyr, it is curious to observe how deeply the misapprehension concerning them had sunk into the minds of the Commissioners. In the Session of 1872 Dr. Franklin gave evidence before the House of Commons in support of the Birmininghame Sewage Bill, and in speaking of Downward Filtration, had his attention called (*Q.* 3769) to the passage already referred to, in which the Commissioners declared their confidence in its permanent efficacy, but at the same time their apprehension that the apparatus on a large scale might give rise to a nuisance, and he then replied, "Yes, at the time that Report was written we had not seen the Merthyr works. They had only been established a few months." So also Mr. W. Hope, V.C., in answer to the late Mr. Horace Lloyd, in the course of his evidence upon the same Bill, gave this explanation of his not having visited the Merthyr works; "*Q.* 2101. I asked if there were anything to be learned there, you would go there?—*A.* If I thought I could learn anything more than I am taught by Dr. Frankland's experiments, I should go there." And again, "*Q.* 2103. But you have never gone to see it?—*A.* Because it tallies exactly with Dr. Frankland's experiments. If the result had not been as good as Dr. Frankland predicted, I should have gone." And the same confidence in the Merthyr fallacy, which distinguished the evidence of Dr. Frankland and Mr. Hope, was equally characteristic of that which was given by the majority of the many eminent experts who supported that Bill, so that when the Bill left Committee the fact stood, founded upon a concurrence of the highest testimony in the kingdom, that the experience of the Merthyr filter beds was identical with the conclusions of the Rivers Pollution Commissioners, and that, the reliability of such experiments having been established, they might safely be accepted as a model for future practice. But the most remarkable incident in the whole history of the Merthyr filter beds is, that Mr. Bailey Denton, at whose instance they were laid down, appears to have participated to some extent in the general misapprehension, and by his public utterances to have assisted in its dissemination, although it must be at once admitted that they exhibit a large amount of contradictory statement. For example, in a Paper by him in the Jour-

nal of the Society of Arts, December 8th, 1871, it is stated (p. 65), "Short as the interval has been since intermittent downward filtration was first suggested by the Rivers Pollution Commissioners, that process has, like irrigation, undergone a change..... The change to which I have referred has arisen on the proof which I have had the satisfaction myself of affording, that vegetation may be grown upon the surface of filtering areas, even when receiving sewage equal to the discharged refuse of 3,000 persons to each acre, thus adding, in the most apposite manner, to the cleansing powers of the soil the skavangering properties of vegetation." And again (p. 66), "Having dwelt upon the practice of irrigation, I ought now to explain the process of intermittent filtration as it may be carried into practice, but as I shall presently deal with it when considering 'Land as a purifier of sewage,' I will only state that by adopting the process as technically described, the liquid refuse of from 1,000 to 3,000 persons—and probably more—may be cleansed by the soil of a single acre of land." On what authority does Mr. Denton state that a proportion of 3,000 persons to an acre may be adopted? Is it on the faith of the Rivers Pollution laboratory experiments, or of the experience of Merthyr? Surely not the latter, for (p. 68) he puts the population contributing sewage to the filter beds at Merthyr at 30,000, which, it will be presently shown, is an excessive estimate, and the acreage at 20 acres, which would only justify a proportion of 1,500 to an acre, or less by one-half than the proportion previously suggested.

The only way in which this apparent inconsistency can be explained, is by supposing that when speaking of the proportion of 3,000 persons to an acre, Mr. Denton alludes merely to the temporary effect of such a proportion; but that when he has in view the permanent purification of the sewage, the proportion must be reduced to 1,000 persons to an acre. In a Report made by him in 1873, suggesting Intermittent Downward Filtration as the best means of disposing of the sewage of Kew, Mortlake, and Barnes he says (p. 54), "The quantity of land, actually required for the purification of sewage of average foulness by intermittent filtration, may be calculated at 1 acre for every 1,000 persons if it be drained 2 yards deep, so as to secure 2 cubic yards of filtering material for every square yard of surface. The Rivers Pollution Commissioners deduced from their laboratory experiments that 1 acre of suitable land drained 2 yards deep might suffice for 3,300 people, and in increasing the quantity of land to 1 acre for 1,000 persons, as I propose to do, the object is to avoid any doubt as to permanency of effect."

When Mr. Bailey Denton gave evidence in support of this scheme before Major Tulloch, R.E., Assoc. Inst. C.E., the Local Government Inspector, who held the usual district inquiry preliminary to the grant of a provisional order, he at once admitted that his supervision of the Merthyr works had been limited to five or six occasional visits, and expressed himself unable to speak definitely as to the extent to which the practice of Downward Filtration had been carried there. Under these circumstances, and for the purpose of arriving at an accurate knowledge of the Merthyr facts, it was considered advisable to procure the attendance of Mr. Harpur, Assoc. Inst, C.E., the Resident Surveyor, under whose immediate superintendence Downward Filtration had been adopted, and had continued in operation from the time of its introduction in January 1871 until the time of the inquiry in April 1874. His evidence is not a little remarkable, considering that it was actually given as an advocate of Intermittent Downward Filtration, objecting to a proposal which would have this effect, to use his own words, "that the valuable process of Downward Intermittent Filtration would be put off very seriously throughout the country."

The following evidence extracted from the short-hand notes of the proceedings, shows the actual facts as to Merthyr, and the true conclusions to be drawn from them, as defining the capacity of Downward Filtration to deal with sewage:—

On p. 57 of the Notes Mr. Harpur is asked: "*Q.* Then we may take it that it was only for five months that the sewage of 25,000 people was put upon 20 acres at Merthyr Tydvil?—*A.* That is the fact; the whole of the sewage. *Q.* And that is the whole of your experience in refer-

ence to the power of 20 acres to receive and deal with satisfactorily the whole of the sewage of the 25,000 people?—*A.* Just so. *Q.* Then in taking 50,000 the Rivers Pollution Commission was in error?—*A.* There was not the sewage of 50,000; nothing like it. *Q.* Then the deductions drawn by the Commissioners in their Report, based upon the sewage of 50,000, must therefore be erroneous?—*A.* Yes; they must be erroneous."

Again, p. 69: "*Q.* What do you consider is the population the sewage from which might be safely drained or turned upon the 20 acres at Merthyr Tydvil?—*A.* I have given that a great deal of consideration, and my opinion is that those 20 acres would take the sewage and the sewage of 12,000 in perpetuity. I do not think they would cleanse the sewage of more than 12,000. *Q.* That is the result of two years' experience and careful watching?—*A.* Yes, it is." So that so far these significant facts are distinctly proved by the Resident Surveyor at Merthyr: (1) That for a short period of five months only the filter beds were exposed to their greatest strain, sewage being applied in the proportion of 1,250 persons to an acre. (2) That the opinion based upon two years' experience is, that if permanent purification is sought, the proportion must not exceed 600 persons to the acre. Before directing attention to the marked contrast between this evidence and the statements of the Commissioners, it will be well to establish its conclusiveness by carrying it a stage further. After stating that he would only recommend Downward Filtration where sufficient land cannot be obtained for irrigation, Mr. Harpur is asked (p. 60): "*Q.* Under such circumstances as those at Merthyr Tydvil, where the land is exceptionally favourable, you would not put more than the 12,000 to the 20 acres?—*A.* No; I do not think it would be safe generally to place more sewage than that of 500 on an acre. *Q.* Not more than 500 persons to an acre is the result of your experience?—*A.* Yes; it is so."

How far, then, are the experiments of the Rivers Pollution Commissioners substantiated, or their statements justified, by the experience of Merthyr? If Mr. Harpur is accurate in his facts and opinions, their statements are erroneous and their experiments fallacious. Instead of the capacity of the land to receive sewage being continuously tested by the application of the sewage of 2,500 to the acre, the greatest temporary strain to which it was ever exposed was in the proportion of 1,250 persons to the acre. Instead of their opinions that the sewage of from 2,000 to 3,300 persons might be cleansed on a single acre of land, Mr. Harpur states that 600 persons to the acre, in his opinion, represents the capacity of the filters. The issue between these opinions is important, and inasmuch as Downward Filtration is by way of marking a new era in the much-vexed question of the disposal of sewage upon land, it is essential that its capacity should be accurately defined by the experience obtained from its practical operation. The truth can only be ascertained and error refuted by a survey of the evidence which has been supplied by such experience. In order to place the Merthyr facts beyond the range of discussion, it is necessary to examine the evidence relating to them in somewhat tedious detail. Mr. Arnold Taylor, one of the Inspectors of the Local Government Board, having visited the works at Merthyr, presented a Report, dated November 8th, 1872, which may be taken as conclusive up to the time when that Report was made. The following are the most important extracts: "The population of the district draining into the river Taff is estimated at 40,000, of whom about 20,000 are living in houses directly connected with the existing sewers; the other 20,000, having cesspool or surface drainage only, or perhaps no drainage at all, contribute but little to the existing volume of sewage. This should be borne in mind, because I see it constantly stated in the newspapers and elsewhere, that the sewage of the population of Merthyr—*i.e.* 40,000 people—is being successfully purified upon 20 acres of land at Troed-y-rhiew. The fact is, that for some four or five months at most, viz. from January to May 1871, the sewage of 20,000 was run on to the 20 acres of filtration area. But after that time, and to the present moment, one-half only of this sewage of 20,000 people has gone to the 20 acres, the other half having, since June 1871, been continuously applied to the 54 acres of adjoining land under ordinary irrigation.

"I do not wish to be misunderstood. The filtration process at Merthyr must be regarded by every one who visits the place as a very great success, and Mr. Denton is justly entitled to the credit of having first applied on a large scale a system which Dr. Frankland had previously worked out in a series of careful laboratory experiments.

"But just because it is so successful, does it seem to me of importance that the exact truth should be stated with respect to earth filtration as a means of sewage purification.

"The exact history of the Merthyr case will be thus: That for some five months, say from January to June 1871, 20 acres of land, most exceptionally situated and very carefully prepared, were found sufficient to purify a volume of sewage from 20,000 persons, equal to a daily discharge of say 900,000 gallons, or at the rate of 45,000 gallons per acre per day. That for the next eighteen months, the same 20 acres are found capable of purifying half this quantity, the rest being distributed and purified over the 54 acres of irrigated area.

"When I saw the land at Troed-y-rhiew last August my impression was this: That the 20 acres of filtration area did show signs here and there of saturation, and that though the appearance of the surface and of the crops grown upon it was wonderful, regard being had to the quantity of sewage which had been poured upon so small an area, yet that the appearance of the crops and the surface of the 54 acres of the adjoining irrigated farm was in all respects the better of the two.

"It is stated by Mr. Harpur that he has dug trial holes at various parts of the filtration area, and that in none of them has he found any sign of earth saturation or of offensiveness. Hence it may be argued that by a continuance of the present intermittent system of filtration, one 5-acre area being in use at a time, whilst the other three are at rest, the land is capable of being used for an indefinite period of time.

"This may be so, but what I urge is, that the 20 acres of earth filters at Merthyr purified the sewage of 20,000 people for at most five or six months; that since then they have purified the sewage of 10,000 people, and that by the end of this year or the early part of next they may have ceased altogether to act as continuous earth filters.

"The Merthyr system may therefore be certainly quoted as an example of successful sewage purification, but the following exceptional favorable conditions and circumstances ought at the same time to be taken into account:

"First, then, at Troed-y-rhiew, where the filtration areas are situated, there is no population which is likely to be at all sensitive on the subject of nuisance from any offensive smells or emanations.

"Second. The surface soil is light, and of a kind the best suited for active filtration.

"Third. The subsoil, a deep bed of open, porous, water-charged gravel, not only acts most favorably as an open filter, but also gives to the sewage liquid, after it has passed through 6 feet of earth, some three or four times its own bulk of pure water.

"These are favoring circumstances which cannot easily be found in combination. They are found at Troed-y-rhiew, and hence, in my opinion, the main cause of the success of the system of intermittent earth filtration as applied to the purification of the Merthyr sewage. But I believe that this success will be even more marked when the larger area for irrigation purposes is completed, for then, if earth filtration be practiced at all, it will only be resorted to on an emergency or in wet or winter weather."

How do the statements of the Rivers Pollution Commissioners stand verified by this evidence? What becomes of the theoretical proportion of 3,300 persons to an acre? or of the illustration afforded by the experience of Merthyr, where, to quote their words, "the sewage of a town of 50,000 inhabitants was then pumped on about 20 acres of land," or in the proportion of 2,500 persons to an acre? Compare this statement with the facts, that, under circumstances so favorable as to be rarely expected in combination, a proportion of 1,000 persons to an acre, according to Mr. Arnold Taylor, was maintained for about five months, but was subsequently reduced to 500 persons to an acre, and so the filters were subjected to a strain somewhat less severe than the ordinary irrigation farm at Bury, where the permanent proportion

observed is 577 persons to an acre, and a far less strain than is imposed upon the Eton sewage farm. This proves that irrigation can, upon the principle contended for by the Rivers Pollution Commissioners, namely, cubical capacity of aerated soil, or soil cleared of subsoil water, outdo Intermittent Downward Filtration in its purifying power; in other words, irrigation is, in some cases, naturally more intensive in its operation than a system of Downward Filtration, for the simple reason that, in some irrigation farms, the subsoil water lies naturally at a lower depth than in a filter bed, where it has been artificially lowered to a depth of 6 feet. With a view of ascertaining the degree of purity of the effluent at Merthyr, various chemical tests were applied. If it be true that deterioration was actually taking place when the proportion of only 500 or 600 persons to the acre was observed, it would seem to be somewhat doubtful whether 1 acre of filter bed drained 6 feet deep could effectually purify even that limited population with permanency of effect; or, to put the case somewhat differently, it would be questionable whether a 6-feet depth of drainage gives a sufficient cubical capacity of oxygen-charged soil to effect permanent purification in the proportion of 500 persons to an acre. This would seem to be the fact, for the results of the experiments at Merthyr in 1871 and 1872, by the Rivers Pollution Commission and the Committee of the British Association, on the utilization of sewage, clearly indicate that such a gradual deterioration was taking place in the quality of the effluent. The following table, based on the experiments of the Rivers Pollution Commission, exhibits the decrease in the percentage of impurity removed from the sewage by the action of the filters in the interval between the months of June and October 1871 :

	In June, 1871.			In October, 1871.		
	Quantity contained in Sewage.	Quantity contained in Effluent.	Percentage removed.	Quantity contained in Sewage.	Quantity contained in Effluent.	Percentage removed.
Total solid mattor.....	54.000	34.600	35.97	49.200	33.480	31.95
Organic carbon.....	2.788	0.249	91.07	1.282	0.323	74.81
Organic nitrogen.....	0.783	0.056	92.85	0.952	0.107	88.76
Ammonia.....	4.854	0.075	98.46	1.280	0.058	95.47
Total combined nitrogen...	4.780	0.349	92.70	2.058	0.455	77.89

A comparison of the two series of experiments made by the Committee of the British Association gives a similar result :

In January, 1872, the quantity of organic nitrogen removed was 96.43 per cent.
In July, 1872, the quantity of organic nitrogen removed was 86.55 per cent.

In the above comparisons the effect of the subsoil water in diluting the sewage is not taken into account.

The Committee of the British Association, in their Report of 1872, p. 151, thus summarise the results of their experiments : "The effluent water this summer was not quite so pure as last winter, but still four-fifths of its nitrogen was in the form of nitrates and nitrites."

It will have been observed that the most recent evidence referred to, as to the operation of the Merthyr filters, has been that of Mr. Harpur in the spring of 1874. There had then been three years' experience of their action, which might have been considered sufficient to form a judgment as to their effect. And yet, in a Paper, submitted to the Conference at the Society of Arts in 1876, Mr. Denton gives color and credence to what might have been justly looked upon as the somewhat faded pretensions of Downward Filtration. First of all, he makes the following statement (p. 23) :—"We have now had sufficient trial of actual works to assure us, first, that the suggestion which Dr. Frankland based upon his laboratory experiments, to the effect that an acre of suitable soil drained 6 feet deep, and used intermittently, would cleanse the sewage of 3,300 peo-

ple, can be realised." What is the "trial of actual works" alluded to as proving the practicability of cleansing sewage with such a proportion of population to soil? The specific experience is referred to in the following statement, but it must be observed that the difference between temporary and permanent effect is not always clearly expressed. It is this (p. 24): "Although experience at Merthyr, Kendal, Walton Convalescent Hospital, and other places, has most conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people, a fact, the importance of which cannot be over-estimated in those cases where land is very difficult to get and very expensive when obtained, I may be pardoned for stating that I do not wish to be considered the advocate of dealing with the sewage in such a concentrated form under all circumstances." To these allegations the Author makes the following distinct and unqualified reply:

1. That experience at Merthyr has never proved that the sewage of 3,300 persons could even be cleansed temporarily upon an acre of land, the greatest proportion which ever obtained there being from 1,000 to 1,250 persons to an acre (*vide* the evidence of Mr. Harpur and Mr. Arnold Taylor).

2. That experience at Merthyr has never conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people; but it has conclusively shown that if permanency of effect be required, the proportion, where the filter beds have a 6-feet depth of drainage, must not exceed 500 persons to the acre.

3. That the case of Walton Convalescent Hospital has never conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people, for the simple reason that the proportion there has never exceeded 400 persons to an acre, as is proved by the following extract from the short-hand notes of the inquiry already referred to, when, in answer to questions, Mr. Denton stated as follows:—"*Q.* Have you ever carried the laboratory experiments of Dr. Frankland into anything like practical effect? —*A.* The Merthyr Tydvil works are nearly three years old, and the works at the Convalescent Hospital at Walton have been in operation four years; once in twenty-four hours the sewage is intermittently applied there. *Q.* What is the population per acre there?—*A.* It varies from 100 to 400. I am not instancing this as a proof that Dr. Frankland's statement is correct." The only further comment to be made upon this evidence of 1874 is this, if the Walton Convalescent Hospital was not cited as substantiating Dr. Frankland's statements, why is it quoted in support of them in the Paper of 1876?

4. That Downward Filtration as practised at Kendal has never conclusively shown that 1 acre of suitable land will efficiently and for a constancy cleanse the liquid refuse of 1,000 people. The facts are given by Mr. Denton, in the Journal of the Society of Arts already referred to, thus (p. 25):—"At Kendal, where there is a population of 13,500, the intermittent downward filtration work has hitherto been confined to about 5 acres of land, contrary to the advice which I gave the Corporation when first consulted, to the effect that 15 acres should be prepared. The experience gained on these 5 acres surpasses all expectation. It confirms, nevertheless, the opinion already stated, that the proper proportion of sewage to land should be that of 1,000 persons to an acre. In this view it appears that the Corporation now concur, for the sewage is not always confined to the 5 acres, but is occasionally applied also to the remaining 10 acres which I had proposed should be prepared for filtration."

Does this mean that the sewage of 13,500 persons has been applied to 5 acres of filter beds, or at the rate of 2,700 persons to an acre? or has no distinction been drawn between population and population directly contributing sewage? To this vague generalization of statement the origin of the Merthyr misapprehension may be traced. Referring to the return furnished from Kendal to the Society of Arts, it appears that, for this population of 13,500 persons, there are only 500 closets in use, so that it is erroneous to speak of the sewage of a population of 13,500 persons draining upon the 5 or 5½ acres of filtration area. What the sewage-contributing population proper is, it is difficult to

estimate, but taking the above limited number of closets, coupled with the fact that middens are principally in use, the sewage probably is not derived from more than one-third of the population. Adopting this view, the sewage of a population of 4,500 would have been dealt with upon a surface area of filter bed of 5½ acres (for 5½ acres, and not 5 acres, as appears from a letter from the Borough Surveyor of Kendal to the Author, dated November 13th, 1876, are the accurate dimensions), which yields a proportion of rather more than 800 persons to the acre. This is, of course, to some extent speculative, in the absence of positive information. But before proceeding to conclusions there are several important elements for consideration. First of all, the sewage is rendered extremely dilute by the enormous infiltration of subsoil water into the sewers; secondly, the depth at which the subsoil water in the filter beds stands below the surface-level is not stated, so that it is impossible to argue upon the capacity of Downward Filtration as practiced at Kendal, inasmuch as the whole principle is based upon the cubical capacity which a 2-yards depth of drainage would afford; thirdly, according to Mr. Denton, and also from information supplied by the Borough Surveyor, the whole 15 acres will soon be required for the purposes of filtration, the present limited surface showing a tendency to become clogged. Then, if the Author is right in the assumption that one-third of the sewage proper passes to the filters there, the history of the operation of Downward Filtration at Kendal is this: That for a time the dilute sewage of the town has been applied to the filter beds in the proportion of about 800 persons to an acre; that such filters have shown symptoms of clogging; and it is, therefore, intended to reduce the proportion from 800 persons to an acre to 300 persons to an acre. If this statement of the Kendal experience be an accurate one (and the Author need hardly say that, as he proceeds upon assumption in this case, and is not dealing with facts proven, he is open to correction), there is nothing in any of the cases cited to establish either the soundness of Dr. Frankland's conclusions or the accuracy of Mr. Denton's statements. Merthyr clearly fails at the touchstone of inquiry, Walton fails on Mr. Denton's own evidence, Kendal it is submitted fails on account of the facts stated, and by obvious parity of reasoning from the circumstances at Merthyr.

Surely it is time that the Merthyr fallacy was stamped out, and yet the advocates of Downward Filtration seem unwilling that it should die. The following extracts from a recent correspondence will, however, it is hoped, supply it with a suitable apotheosis. Mr. Denton commences his Paper by introducing (p. 25) a letter from himself, dated May 11th, 1875, addressed to Mr. Jones, the Chairman of the Merthyr Local Board, which, will "satisfy the most sceptical that the value of intermittent downward filtration is as great in combination with surface irrigation on a wide area as when adopted by itself on a small one." In this letter, after expressing apprehension lest the extension of the irrigation area should be interpreted as meaning the abandonment of Downward Filtration, he thus concludes: "Will you kindly say if your Board has changed its mind as to the retention of the filtration areas as part of its permanent works, and if so, what has led to such change?" And again, "I am glad to find that Mr. Dyke (the Medical Officer of the district) has the same confidence in the permanency of their action as I have. In his letter to me of the 6th of May last, he says: "There is still no evidence of any clogging or over-saturation of the beds." In his reply (also set out in the same Paper) Mr. Jones states that the Board contemplates no abandonment of the filtration areas, but looks upon them as a "safety valve." Then the Paper concludes, so far as Merthyr is concerned, with the following observations (p. 25): "If anything more than this is needed to prove the thorough success of the intermittent downward filtration work at Merthyr, I cannot do better than point to the following passages of a letter from Mr. Dyke, the medical officer of the district, who wrote me as lately as July last in the following terms." The gist of Mr. Dyke's letter was to the effect that filtration was perfect, the effluent pure, and the vegetables grown on the filters had been eaten without producing diarrhœa; and then the important statement follows "that there

has never been any sign of clogging or over-saturation." Can anything more be needed to prove the thorough success of the Intermittent Downward Filtration work at Merthyr? Only this letter from Mr. Harpur, which states how this success has been achieved. It is addressed to the Author, is dated 8th November, 1876, and runs thus:

"The total area of land acquired by the Board for sewage purposes, including roads, rivers, unsuitable and at present unformed land, is 334 acres.

"The sewage is now being applied to 210 acres, including the 20 acres of filtration areas. Of the land acquired about 90 acres have yet to be formed for the reception of sewage.

"For the last four years no more sewage has been applied to each acre of the filtration areas than to an acre of the irrigated ground.

"The population draining to the sewage farms is 48,000. Each acre of both the irrigation land and the filtration areas receives the sewage of 229 persons.

"The filtration areas do not show any sign of deterioration.

"It is intended to use them permanently for irrigation."

Can anything more be needed "to prove the thorough success of the Intermittent Downward Filtration work at Merthyr" than the facts:

(1) That for the last four years the filter beds have never received the sewage of more than 229 persons to the acre, and yet up to the present time "there is no evidence of any clogging or over-saturation of the beds."

(2) That the filter beds are to be preserved—for what? to perform *en permanence* the functions of ordinary irrigation.

Conclusions.—1. Intermittent Downward Filtration is merely an artificial production of intensified irrigation, and is a useful process to adopt, where land for irrigation cannot reasonably be acquired, or where the necessary depth of soil free from subsoil water cannot be obtained without recourse to artificial drainage.

2. That there is no evidence to show that a larger proportion than the sewage of 500 persons can be permanently purified upon an acre drained 6 feet deep, though there is positive evidence to show that it must not be exceeded, and that this proportion therefore represents the capacity of downward filtration over and through such area and depth of soil.

3. That Dr. Frankland's experiments are strained in the conclusions drawn from them by the Rivers Pollution Commissioners, and that such conclusions, instead of having been confirmed, have been refuted by subsequent practice.

4. That the statements with regard to Merthyr are without foundation or justification; the true facts being that for five months the sewage was applied in the proportion of 1,000, or at most 1,250, persons to an acre, then of 500 persons to an acre, and afterwards permanently of 229 persons to an acre. That though the formation necessary for downward filtration has been preserved, to all intents and purposes the filters are performing the permanent functions of an ordinary sewage irrigation farm.

III. THE DRY EARTH SYSTEM.

The first and most prominent objection to the introduction of this system into any town is, that instead of being substitutive for a water-carriage system, it is merely supplementary to it; for there must still be a water-carriage system in every town where the dry earth system is adopted, independent of it, which in its capacity shall be equivalent to such a water-carriage system as would be laid down even if the dry earth system was not practised. Therefore the cost of the dry earth system must be superadded to the cost of the water-carriage system, and thus the expense to be incurred by the town in respect of its drainage must be increased without any additional benefit being conferred, but, on the contrary, enormous additional expenditure, disadvantage, and difficulty.

To make good these propositions, assume that it is proposed to introduce the dry earth system into the metropolis, which may be taken to contain a population of 4,200,000 souls, and a superficial area of 150 square miles, composed to a large extent of roof and paved surface. The rain falling upon this hard surface cannot be absorbed, and must flow somewhere. Can the dry earth system take it? No, for it only proposes to intercept the solid refuse of the town; therefore

a system of sewers at once becomes a necessity. Then, again, what is to become of the dry-weather flow of sewage or the sewage proper, the dimensions of which are measured by the water supply of a town? The water supply of London is 30 gallons a head per day, which gives a daily volume of sewage to be disposed of amounting to 126,000,000 gallons in twenty-fonr hours. Can the dry earth system deal with this great bulk of liquid? It does not profess to. Therefore there must be a system of sewers to receive it, and a system, moreover, of equivalent magnitude to that which would be adopted if the dry earth system were not in the town; for the dry earth system does not reduce to any appreciable extent the volume of sewage produced, inasmuch as its proper province is to intercept the solid matters, with a small portion of the liquid, which would otherwise be carried away in the water supply. Nor does the dry earth system diminish to any great extent the foulness of the sewage, inasmuch as, according to the Rivers Pollution Commissioners, the foulness of the solid refuse is only one-seventh of the foulness of the liquid, and the extraction therefore of so subordinate a polluting element from the sewage could not much affect the degree of its general pollution. Of course some portion of the liquid refuse is disposed of by the dry earth system, and in the sense, therefore, that the volume of foul liquid in the sewers is diminished in quantity and more diluted in quality it may be said that its foulness is reduced.

Again, if the dry earth system is to be a substitutive system, supplanting all other systems, what is to become of the garbage and washings of the streets, manure consequent on traffic, liquid refuse from breweries, slaughter-houses, cattle markets, urinals, factories where offensive trades are carried on, and to resolve the dry weather flow into some of its constituent parts, the household slops from kitchens and bedchambers? Either streets must fail to accumulate refuse, such trades and institutions cease to exist, slops and ablutions be banished, or some provision must be made for them. This provision can only be by means of a water-carriage system of sewers. Hence the first proposition becomes manifest, that given the dry earth system, the water-carriage system is still a necessity. If this be so, it follows as a natural consequence that the cost of the dry earth system must be superadded to the cost of the water-carriage system, and that as the dry earth system disposes of nothing which is not disposed of by the water-carriage system, it imposes, therefore, an additional expense without conferring any corresponding advantage.

To illustrate the statement that its operation would be attended with great cost and enormous difficulty the following figures, which proceed upon the assumption of its introduction into the metropolis, may prove instructive.

Moule's Earth Closet System as applied to London.—4½ lbs. of earth per head are equal to 14.66 cwt. per annum, or (on a population of 4,200,000) 3,078,600 tons, cubic yards, or cart loads; or 10,000 cart loads per day for six days in the week. The same quantity would have to be carried out, with the addition of 470 loads of fæcal matter. There are 450,000 houses in London; therefore each cart would deliver earth and remove soil from 45 houses per day. Suppose two pails to each house equal to 900,000 pails, then the figures will stand thus:

(1) *Prime cost of introduction of system.*

	£
450,000 houses in London; water-closets removed, earth closets substituted, and metallic wagons provided, say, 700,000 closets, at £10 each	7,000,000
10,000 carts and horses. { horses, £40 / carts, £20	
£60×10,000	600,000
3,078,600 cubic yards of earth taken off land ½ yard deep=1,272 acres, say two years' supply = 2,544 acres at £300	763,200
Drying sheds (say 600 acres) at £1.200	720,000
	9,083,200
10 per cent. for London depots, offices, &c	908,320
	9,991,520

(2) *Annual expenditure.*

	£
3,078,600 cubic yards carted in 10,000 carts per annum at 12s.=£6,000 (1 man 4s., 1 boy 2s., 1 horse 4s., wear and tear of cart 2s.)	1,878,000
Labor in digging, loading and unloading carts, railway to London and back at 2s. per yard	307,860
	2,185,860

	£
Representing at 4 %..	43,717,200
	9,991,520
	53,708,720

These figures have not been strained; on the contrary, each item has been stated upon the most moderate estimate, and in some cases evidently at too low a figure. So that, after having constructed and paid for a water-carriage system, an additional preliminary expenditure of £9,991,520 would be needed to introduce the dry earth system, and an annual expenditure of £2,185,860 to maintain it, which, capitalized at four per cent. and added to the original outlay, represents the enormous sum of £53,708,720, and all this without effecting anything which the water-carriage system is not competent to perform. These figures also illustrate the cumbrous machinery which would be required to give practical existence to the system on a large scale. Where are thousands of acres to be obtained near London for the supply of mould? How is the constant manipulation of sewage refuse to be tolerated in an English town? And, lastly, how are the already overcrowded streets to accomodate the multitude of carts which would be let loose upon them, when the number of such carts would actually exceed the existing number of hansoms and four-wheeled cabs, omnibuses, and tramcars?

Enough has been said to demonstrate the impracticability of introducing the dry earth system into a populous town. That it has a province cannot be denied, but it is essentially a limited one. It is well adapted for the wants of small rural villages like those of Halton and Aston Clinton in Buckinghamshire, with a joint total of 55 cottages, where it has been adopted, and of detached houses so situated that an abundance of suitable earth can be obtained. So also it may be appropriately applied in the case of detached public buildings under some general control, such as hospitals, workhouses, almshouses, and asylums, always premising, as a condition precedent to its adoption, that the soil in the neighborhood should be of a porous character, so as to be capable of absorbing the liquid house refuse undisposed of by the dry earth system, which is of so decomposing and putrescible a character that if allowed to stagnate in trenches or open ditches it would soon poison the atmosphere and generate malaria. But when it is proposed to introduce it into towns, the conditions are, as has been shown, entirely changed, and the sphere of its usefulnes sbecomes narrowed in proportion as population increases. In fact it may be laid down as a universal proposition, that the applicability of the dry earth system becomes diminished in the inverse ratio to the increase of population to which it is proposed to apply it. The general conclusions, therefore, which must be laid down with regard to this system are:

1. That its adoption in the case of large towns would be costly, cumbrous, useless, and virtually impracticable.

2. That its use must be limited to rural places and detached buildings where a water-carriage system cannot easily be constructed.

IV. THE LIERNUR OR PNEUMATIC SYSTEM.

This system is one of those which still persists in asserting a pertinacious and pernicious vitality in spite of the experience which ought long ago to have extinguished it, and would have done so, had it not been for the energy of those interested in its survivorship. There appear no less than seven notices of it in the Society of Arts Journal of May 1876, one by Captain Liernur, one by T. A. Van der Kloes, Director of Public Works, Dordrecht, and the other five by Mr. Adam Scott, Captain Liernur's agent in this country. But as the term "Liernur System" may not suggest to the minds of all persons the principle upon which it is based and the machinery by which it is applied, the following description extracted from a pamphlet by Mr. Adam Scott, and verified by the inventor's specification, may assist a proper comprehension of its defects.

"In a building, in any convenient part of the town, is placed a steam engine, which drives an air pump, so as to maintain about three-fourths vacuum in certain cast-iron hermetically-closed reservoirs sunk below the floor.

"From these reservoirs central pipes radiate in all directions, following the main streets. On these central pipes are

laid, from distance to distance, street reservoirs sunk below the pavement.

"From the street reservoirs, up and down the street, are main pipes, communicating by short branch pipes with the closets of each house.

"All the junctions of pipes with reservoirs are furnished with cocks so that they can be shut off or turned on at pleasure, like water mains, and are got at by cock boxes, and turned by keys in the ordinary way.

"The vacuum created in the central building reservoirs can thus be communicated to any given street reservoir, so as to furnish the motive power by which, when the connections with the houses are opened, all the closets are simultaneously emptied.

"When their contents reach the central reservoir, they are in like manner forced through the central tubes to the reservoirs under the central building, and thence transfered by means of vacuum power to the hermetically-closed tanks above the floor of the building. From these retorts the matter is decanted in a fluid form in barrels, for immediate transport to the country, by means of hermetically-closed apparatus."

As regards the inception of this system, it is said that Captain Liernur got his idea from the rude pneumatic system in use at Milan, where a vacuum is obtained by first filling the tanks with water and then exhausting them. The water is carried about in ox carts. The system was first introduced into Prague in 1863 for some military barracks; later into an insane asylum at Hanau. In answer to the statement of the Berlin Commission, that in these places it had proved offensive, and so unsatisfactory as not to be extended, Captain Liernur stated that the first attempts had been improved upon, and that in Holland he had overcome the difficulties which had proved so troublesome at Prague and Hanau. A Commission at the Hague recommended Liernur's system for that city in 1867, but it has never been introduced there. It has had a similar fate lately in Rotterdam. In St. Petersburg, at the beginning of last year, Captain Liernur was making an experimental introduction of his method, with the understanding that the city was not to bear any of the expense, and that no extension was to be made unless the system proved satisfactory. About the same time he was also preparing plans, which he hoped might be accepted, for Gaeta and Naples. His system has been partially introduced at Leyden, Amsterdam, and Dordrecht in Holland, but none of the cities or towns in England have been persuaded to follow the example of their Dutch neighbors.

The objections to the system, which render its adoption impracticable, may be shortly stated. The most important is that which has already been mentioned with regard to the dry earth system, and which apart from all other considerations, is absolutely fatal, namely, (1) that the Liernur system only deals with the solid refuse and a limited quantity of liquid, and is therefore merely supplementary to a water-carriage system, thus entailing additional cost and conferring no corresponding advantage. (2) The machinery by which the pneumatic system is applied, consisting principally of wrought-iron pipes and chambers, is enormously expensive, and of limited capacity as compared with brickwork sewers. (3) That it is complicated and liable to get out of order. (4) That the closet arrangements for the houses, as well as the operation of decanting sewers, are offensive, and such as could not be tolerated in an English town.

From the evidence afforded by the experience of the system in Holland, it may be premised, in the first place, that in the towns where the system has been introduced in that country, there was absolutely no previous sanitary provision, the whole sewage being either thrown by hand, or allowed to pass away into the tide-locked canals characteristic of the Netherlands towns, so that the introduction of any system was of necessity an improvement on the former unsatisfactory condition of things.

1. *Leyden.*—Plans were accepted for Leyden in 1870. The population is 40,000, and out of this population 1,200 people in the poorest quarter have had the Liernur system applied to their houses. The evidence as to the measure of success with which its operation has been attended has been a matter of animated discussion. In a letter, addressed on April 1st, 1873, by the Master of Public Works, J. W. Schaap, to the Magistrate

President of the Commission of Manufacturing Industry, he speaks in the following favourable terms of the system (Seventh Annual Report of the State Board of Health of Massachusetts, p. 319): "While it cannot be denied that the expenses of introducing the system and the necessary experiments were greatly in excess of what was anticipated, that the amount received for the fæcal material was less than was anticipated, and that the interest on the money and the instalment paid must be taken into account, yet a favourable judgment, as to the result, must remain." And again, "Therefore the great question concerning this matter is to be looked upon as entirely settled, and the system deserves recommendation to extension everywhere as well as in this city." So far the opinion was satisfactory, but it was soon to undergo a change. In one of his Papers to the Society of Arts, Mr. Scott states, that it was reported that a Government Commission from this country had visited Holland to inquire into the Liernur system. After expressing doubts as to the existence of such a Commission, he refers to their reported conclusions (p. 60): "as these have thus, in an irregular way, become public, it is right I should, to prevent persons being misled, record the fact that most of the so-called conclusions are misleading, and some of them, in dealing with matters of fact, are simply untrue, as I can show by official letters in my possession. For instance, one of the statements made is that the system is not to be further extended at Amsterdam and Leyden. I have spoken above as to Leyden." On referring back Mr. Scott appears to have said: "I may add to this that the Commission for Public Works have reported in favor of extending the system to the whole town of 40,000 people. In that report they designate it as 'the system of the future for all large towns.' The Financial Commission have reported in similar terms, as have also the Mayor and Aldermen." Surely there is a strange discrepancy of statement somewhere. In his Paper to the Conference at the Society of Arts on the 9th and 10th of May, 1876, Mr. Scott asserts that the Government Commission, if it existed, has been guilty of untruth, and that the Mayor of Leyden had actually reported in favor of the extension of the Liernur system to the whole city. But how can this statement be reconciled with the following opinion expressed by the Mayor on the 21st of January preceding? Replying to the United States Consul at Rotterdam, he says (his letter being published in the Seventh Annual Report of the State Board of Health of Massachusetts, p. 318), "Meanwhile there exists for the present no intention to extend the system in other parts of the city, because of the considerable expense involved in so doing." And again, in conclusion, "Although the experiment with the Liernur system, taken in this city from a technical point of view, may be said to have entirely succeeded, the financial results, however, must become considerably more favorable before an extension of the system will be resolved upon." If, then, the Mayor, to whom Mr. Scott refers, be taken as the best interpreter of his own sentiments, and of the intentions of his fellow-townsmen, the Government Commission, if it existed, was right after all, and did not state what was "simply untrue"; but Mr. Scott must himself be in error with regard to the "matters of fact." The system, then, is not to be extended at Leyden, on account of its cost.

But perhaps the most suggestive and pertinent evidence which has been contributed, with reference to the operation of the system at Leyden, is that which is contained in a Report by a Committee of the Town Council of Southport, which was appointed, at the time when its adoption for Southport was under consideration, to visit Leyden and report upon it. The Report is dated December 15th, 1874. As the statements and opinion expressed apply with equal force to its operation in other localities, and go far to prove the objections which have been raised against its use, it will be expedient to refer to them. The following are the more important passages:—"It should be stated that no slop, or waste water, passes into the Liernur closets. These liquids are disposed of in the quarter sewered on the Liernur system, in the same way as in other parts of the city. Neither does kitchen waste go into the closets, so that the system, as developed at Leyden, is one of collection of human excreta only, and no other

duty is subserved by it." "In order to complete the statement of what we observed at Leyden, it is necessary to say that 'sewers,' as we understand the term, do not exist there. The canals which intersect the city in every direction are the sewers, and house drains enter the nearest canal at the most available point, taking apparently the most direct route without the slightest care or regard as to whether they go under houses or not. This primitive method appears to have prevailed from time immemorial." "A pneumatic system of collecting human excreta would, therefore, relieve the sewers of no appreciable amount of their contents under the present, or even a universal watercloset system. The daily collection at Leyden from the Liernur closet is only at the rate of about a quarter of a gallon per head, so that even if this were much more augmented than would be compatible with any economical manufacture of 'poudrette' the relief afforded to the sewers, however valuable as regards the quality of their contents, could, as regards quantity passed in, be altogether insignificant. It is clear, then, that the pneumatic system will not, if adopted, relieve the borough of the cost of constructing new sewers, which must be of sufficient capacity to carry away, not only the daily flow of between 30 and 40 gallons per head of a rapidly increasing population, but the storm water, which constantly increases in volume as a larger area of the borough is built over and paved, and less of the rainfall sinks into the soil itself." "Captain Liernur himself put down £4 per head of population as the probable cost of applying the system here."

"The impression of your deputation is:

"1. That the system of sewerage already adopted by the Council would be absolutely necessary, even if the pneumatic system were in actual operation in the borough.

"2. That the pneumatic system is highly ingenious and efficient, and probably highly meritorious in a sanitary sense also, though no statistics appear to have been collected which would give us a measure of its excellence.

"3. That in a town of so large an area as Southport, relatively to population, the pneumatic sewerage works would be enormously costly to put down and maintain.

"4. That the amount of revenue derivable is very difficult to estimate.

"5. That, from a financial point of view, it would, therefore, be a great experiment; and,

"6. That if experience in England should at any future time demonstrate in a fuller and more complete manner than has been done at Leyden, that the pneumatic system is, as has been claimed for it, 'an engineering, a sanitary, and a financial success,' it will be as open to Southport as to any other place to lay it down and profit by the practical experience of places having larger means to undertake costly experiments."

The above Report proves that the Liernur system is merely supplementary, both in its operation and its cost; that it disposes of nothing that the water-carriage system cannot dispose of without its assistance; and that there is no sanitary advantage to be gained by its adoption. On the question of cost, it is to be observed that Captain Liernur put the cost of introducing the system at £4 per head of population at Southport, as against £2 5*s.* at Leyden. Making allowance for the difference in the price of labor between the two countries, it is probable that £4 per head in England is considerably below the mark; but adopting it for the purpose of argument, and taking the population of London at 4,200,000, the cost of the introduction of this system into the metropolis would reach the enormous total of £16,800,000; and to this expenditure the cost of the main-drainage system, which would be in no sense superseded by the new system, would have to be superadded. It is difficult to estimate what the annual expenditure for the maintenance and working of the system would be; though one thing is sufficiently clear, that no profitable return from the manufacture of 'poudrette' could be looked for in England.

Assuming the cost of maintenance and working at 2*s.* a head, this would represent for London an annual outlay of £420,000, which, capitalised at £4 per cent. would require £10,500,000 to be raised; and adding this sum to the prime cost, it would appear that the introduction of the system into the metropolis

would involve an expenditure of £27,300-000. It is worthy of remark that it is customary in Continental towns to remove the solid refuse by manual labor, at a cost largely in excess of anything in operation in England, and the annual cost, therefore, of the pneumatic system would not commend itself so strongly as an objection abroad as it would in this country.

2. *Amsterdam.*—Mr. Scott, in his Paper of May 1876, on the operation of the system at Amsterdam, quotes passages from a Decree of the Common Council, issued on the 10th of April, 1873—an account of the system by Dr. Egeling, of the Hague, which appeared in "Public Health," November 2nd, 1874—and a letter from Mr. Bergsma, of Amsterdam, dated August, 1874, in proof of the success with which its adoption has been attended there. Without going so far back in point of time, the following extracts from the Seventh Annual Report of the State Board of Health of Massachusetts, United States, published in January 1876, which treats of this system from personal observation, sufficiently indicate the measure of success with which its practical operation has been attended. The writer says (p. 312). "In Amsterdam, the odors from the canals have been for years extremely offensive. They are all open sewers, with no current, and foul gases are constantly bubbling up during the summer. During winter the offence is less, and arises chiefly from the distribution of so much filth upon the ice. Naturally, the authorities were willing to try any system which promised any solution of their difficulty. They adopted the Liernur system in one of the poorest quarters of the city in 1870. On the 10th of April, 1872 Mayor den Tex and the aldermen decided upon its compulsory adoption in seven other small districts. At the present time, it has been introduced for a population of 6,000, or one-fiftieth of the whole city. Mayor den Tex, and the present Master of Public Works, state that it has given entire satisfaction in the poorer parts of the city, where there was absolutely no accomodation before, and where the closets connected with it are out of doors. They state, also, that its first cost renders it doubtful whether it will be extended even there; and that among the better classes the system is considered inferior to waterclosets and cesspools." This extract contrasts strangely with Mr. Scott's Report, as to the extension of the system at Amsterdam. Again: "Captain Liernur's calculations of cost, although very high, provide for the removal of excrement alone. With his system, there must be also sewers for rain-water, street drainage, slops, &c. He would have separate pipes, too, for the drainage of the soil." Again: "By the politeness of Mr. Bergsma, Secretary of the Board of Works of Amsterdam, a friend of the system, I was able to see it in actual operation.

"The emptying of the tanks was complete, rapid, and, as far at I could see, successful. There was no trace of odor. In the central building, where the matter was transferred to barrels, and in its immediate vicinity, the stench was very great. In the houses of the poorest class, where the house is used by several families, they become soiled, and in some cases filled to overflowing, before any one takes care of them. They become clogged occasionally by coffee-grounds, ashes, &c., which will find their way into them. They are not as offensive as the midden, or privy, still to be found in many large cities. They are in all cases out of doors, and the people who use them prefer them to the arrangements which existed before their introduction.

"In a few houses of the middle class, where they are in the yards, a few rods from the houses, they were scrupulously clean, received frequent washing, and were not offensive. In a primary schoolhouse, where the closets were separated by only a narrow passage-way from the class-rooms, they were very frequently washed, and although there was a slight disagreeable odor, there was nothing really offensive at the time of my visit. It is undoubtedly true, as the teacher said, that the closets are much more satisfactory than anything which they had ever had before.

"In the houses of the better class, there is so much complaint of the bad odor from the closets, that they get rid of it as best they can by flushing, with a sudden dash of a large quantity of water, after each use of the seat. Occasionally they become entirely clogged, when the

odors are simply insupportable. Mr. Dyck, a resident of Amsterdam, who has also a farm in the country, states that twice in one year this intolerable stench drove him and his family entirely out of his house, until the obstructions could be removed.

"Captain Liernur proposes to meet this difficulty by automatic waterclosets, using only one litre of water at each time of use; but they have not been put to the test of practice, and so small a quantity can be of no more service there than in our ordinary hopper closets.

"A part of the original plan was to sell the excrement at a remunerative price; but people of the neater class cannot be prevented from flushing their closets liberally, and the contents of the reservoirs contain so large a proportion of water as to have the general appearance of ordinary sewage, except in color. Dr. Amersfordt made a contract with the city to take the whole of it, to be delivered on his farm at 11½ cents (U. S. currency) for each 100 litres. The contract expired January 1, 1875, and has not been renewed, for two reasons. Dr. Amersfordt states that the distribution of largely-diluted manure from barrels is costly and difficult; also that, when delivered to him in the winter, it is often frozen in the barrels. It is now sold for 16¾ cents (U. S. currency), delivered by boats on the farms, during the summer only. In winter it is carted down below the city and thrown into the harbor, as it cannot be sold."

Thus the example of Amsterdam proves the substantial character of some of the objections which have been urged against the system. For instance, it is abundantly clear that the central building, where the process of decanting the liquid into barrels goes on, is an institution which could never be tolerated in an English town; that the closets are of such a character that, though they might be appreciated by the poorer classes in the open air, would be insufferable as applied to the wants of a high-class population; that the manufacture of manure can never be attended with profit, first, because the closets can only be preserved in a sanitary state by a copious use of water, which water is fatal to the efficient manufacture of "poudrette," and, secondly, because it cannot command a sale.

3. *Dordrecht.*—At Dordrecht, the Liernur system was applied in 1875, upon an area of 17,300 metres, containing a population of 800 inhabitants, distributed over 128 houses fitted with 117 privies. The great feature of its operation there appears to be the manufacture of poudrette on a large scale, and a provisional project for the extension of the system to other parts of the city is contingent upon the success of this manufacture. In his account of the system at Dordrecht, published on the 7th of October, 1875, which appears in the Journal of the Society of Arts of the following May, Mr. T. A. Van der Kloes, Director of Public Works there, states that it would be several months before the "poudrette scheme" could be in regular operation, and he is not therefore in a position to supply statistics with regard to its manufacture. In a letter addressed, on the 20th of January, 1876, by D. W. Hoop, the Mayor of Dordrecht, to the Honorable Frederick Schütz, United States Consul at Rotterdam, the Mayor states that "the extension of the above-mentioned provisional project is delayed, awaiting the results of the poudrette preparations, with regard to which it is thought that sufficient information will be obtained within a few months;" and again, in conclusion, "with regard to the profit on the capital invested in the system, nothing can be stated as yet with certainty, as this community finds itself still too undecided to do so definitely. While the experiment is being carried on, we await more definite regulations from the person who has the contract for cleansing the city."

So that so far poudrette has not proved a financial success at Dordrecht. At Leyden, the Mayor's letter proves that it has been a financial failure, and the same result has followed the manufacture of manure by Dr. Amersfordt at Amsterdem. In addition to this practical experience, the Report of the State Board of Health for Massachusetts (p 317) concludes by saying, "It should be remembered that a similar experiment failed in Amsterdam twenty years ago, that the Paris poudrette sold for one twentieth of the value placed upon it by the chemists; and that an English com-

pany has become bankrupt in attempting to pay two francs a cubic mètre for the contents of the cesspools in Paris, leaving several hundred thousand cubic mètres at Bondy, of which the authorities would be glad to rid themselves."

Surely nothing more is wanted in the way of practical proof to point the irresistable conclusion: that though the Liernur system may be used with partial and costly advantage in the tide-locked cities of the Hague, where a system of sewerage is said to be impracticable, the population is not fastidious in its notions, and anything in the nature of a system must be an improvement on the previous unsanitary condition, it can never for one moment have a place in the operations of the English engineer.

V. SEABOARD AND TIDAL OUTFALLS.

Having regard to the unsuitability and costliness of chemical processes, and of the dry earth and Liernur systems, and the many difficulties, financial and otherwise, which attach to the disposition of sewage upon land, there can be but little doubt that, given a seaboard town, the proper destination of the sewage is the sea. By some, who insist strongly on the value of sewage, it has been objected that such means of disposal are, in fact, an absolute waste of most precious material—material which, if properly handled, must constitute in itself an almost inexhaustible mine of wealth. But day by day the belief that sewage possesses any recuperative value is becoming rudely dispelled, and the doctrine is gaining ground that, instead of keeping sewage at the door as though it were a friend, the right view is to treat it as an enemy, to get rid of which by any means or at any cost should be the primary consideration.

But though such an outfall certainly suggests, in the case of a seaboard town, a natural, economical, and feasible method of dealing with its refuse, there are a few points affecting its construction and position, such as the propriety of the tide-locked outfalls, the course of currents, silting up, which are more or less matters of controversy. Into the first of these points, a tide-locked out-fall, it is not proposed to enter in this Paper, as it comes more properly within the province of a discussion upon the principles of sewer construction than the disposition of sewage at the out-fall. As to the second point, namely, course of currents, it may be laid down as a general rule that, assuming any doubt to exist with regard to the force or set of the currents to which the sewage is to be committed, careful float observations should be taken with a view to preclude the possibility of its being returned upon the beach. If such precautions are taken, there ought to be no special difficulty in guarding against the occurrence of such a return. The last point, or the question of silting-up at the outfall, is one which affects tidal rivers rather than marine outfalls. But if the site for such outfall be judiciously selected, and proper means be taken, in the town which drains to the outfall, for the exclusion of silt and heavy matters by catchpits and an efficient system of scavenging, there can be little reasonable apprehensions of silting-up taking place. At the metropolitan outfalls, no less a quantity than 120,000,000 gallons of sewage, taking the dry-weather flow alone, is passed daily into the river—a volume of sewage equivalent to a fair sized stream—and yet no silting-up has occurred. In fact, it would seem to be a logical inference, in the absence of disturbing causes, that where the velocity of the current into which the sewage is discharged is greater than the velocity of the current which carries it down through the sewers to the outfall, there cannot be much danger of silting-up or interfering with the navigable channel. Of course it is difficult to frame a rule to meet all cases. Much must depend upon the means taken to exclude heavy matters from the sewers, and much upon the character of the locality sewered, some localities producing far more detritus than others. Then, again, the amount of sewage discharged, the sectional area of the river, the volume of water in its channel, and the velocity of the current, are all items in the consideration of the propriety of the outfall, so far as silting-up is concerned. But still it may be accepted as a generally sound proposition, that where efficient means are adopted for the exclusion of heavy matters, such as road detritus, from the sewers, sewage may be discharged into tidal rivers without any material amount of silting-up taking place at the outfall.

This completes the classification which the Author adopted for the purpose of reviewing the various processes or systems in practical use for the disposal or utilization of town sewage. He now ventures, referring once more to such classification, to submit the following definite conclusions for the consideration of The Institution of Civil Engineers, in the hope that they will induce such a discussion as may tend to promote a more unanimous opinion, than at present appears to exist, upon the various questions which attach to their consideration:

1. TREATMENT WITH CHEMICALS.

Conclusions—No chemical process can efficiently deal single-handed with sewage, but must be assisted by subsequent natural or artificial filtration of the treated sewage, and therefore no chemical process *per se* should be adopted for the purification of town sewage.

2. APPLICATION OF SEWAGE TO LAND.

(*a*) *Irrigation.*

Conclusions—That where land can be reasonably acquired, irrigation is the best and most satisfactory known system for the disposal of sewage. That no profit must be expected from the cultivation of crops by the sanitary authority, and only a moderate one by the farmer. That no definite standard can be laid down as to the proportion population should bear to acreage.

(*b*) *Intermittent Downward Filtration.*

Conclusions—That Intermittent Downward Filtration may be practiced, where irrigation cannot be reasonably adopted. That experience shows that the permanent proportion of population to acreage, where land is drained six feet deep, should in no case exceed 500 or 600 persons to an acre. That the term Intermittent Downward Filtration means no more than the production by deep drainage of a state of things frequently found in irrigation, and that irrigation can in some cases accommodate a larger proportion of population to acreage than Intermittent Downward Filtration. That Intermittent Downward Filtration, as expounded and explained by the Rivers Pollution Commissioners, has never had and never can have any practical existence.

3. THE DRY EARTH SYSTEM.

Conclusion—That the dry earth system can never be adopted for the purpose of dealing with town sewage, but may be occasionally used with advantage in small hamlets or detached buildings or institutions.

4. THE LIERNUR OR PNEUMATIC SYSTEM.

Conclusion—That the Liernur system is of such a character that it should never be imported into an English town.

5. SEABOARD OR TIDAL OUTFALLS.

Conclusion—That towns situated upon the sea-coast, or within the tidal range of rivers, should avail themselves of the means of outfall thus presented, as affording the most economical and efficient means of dealing with their sewage, careful regard being always had to the position of the outfall. That proper precautions being observed for the purpose of excluding silt from the sewers, and care being taken in the selection of outfalls upon the banks of tidal rivers, there is no reasonable danger of the silting-up of the navigable channel.

TORPEDO PRACTICE.

From "Iron."

The actual use of torpedoes as engines of war, though theoretically most valuable both for attack and defence, has drawbacks which are worth considering. We may refer, by way of evidence, to Captain Scott's remark on Mr. Donaldson's paper in regard to the Whitehead torpedoes—that every ship of war carrying a supply of these missiles, carries a terrible and novel source of danger to herself. Again, in the present war, it is reported that, with the aid of skilled

divers, torpedoes can be successfully disarmed. It is not difficult, therefore, to understand that the manufacture of torpedoes is one thing, but that their successful use is totally different. For coast protection there are two classes of torpedoes, the mechanical and the electric. At the present time, except in peculiar circumstances, the mechanical torpedo presents so many disadvantages —not the least of which is that its success depends a great deal on accident, and is, consequently, very problematical —that it may almost be excluded from consideration. Yet, when mention is made of the use of torpedoes during the present war on the Danube or elsewhere, it would not do to assume that the mechanical torpedo is discarded. This weapon is useful enough if it is properly planted, if it is properly made, if a great many other considerations have been carefully noted, and if, finally, luck is on its side. But, once laid down, it cannot be tested, nor can it be manœuvred in any way. It is as likely to injure friend as foe, and is not unlikely to be found perfectly harmless to both. In fact, it is a two-edged weapon, which is as dangerous as it is useful, and it proved its terrible unsteadfastness in a variety of ways during the American War. Now, when it is reported that the Turks are prepared to render Russian torpedoes inoperative, reference is evidently made to this class of weapon, which can easily be ruined without risk of serious danger. The electric torpedo is, however, a more formidable weapon, and can hardly be destroyed or ruined, except by accident, or by taking advantage of extraordinary carelessness on the part of those who are interested in its safety. The deadly nature of this weapon may be realized by remembering that the operator is on shore, undisturbed, with plenty of time for quiet and accurate calculation, and dependent only on nerve for the success of his torpedo. But, and this "but" is very large, the use of electricity, especially in a case like this, where the results are so serious, requires a large exercise of dexterity and delicacy. The smallest deviation from the prescribed course may lead to an awful disaster, and a slight want of nerve may send a friend instead of an enemy to the bottom. In fact, the position of the operator is not unlike that of a pointsman or signalman on a railway. Captain Fisher places this in a strong but intelligible light in his remark that "when that most trying time comes in which the utter destruction of an enemy's ship may rest solely on the operator, he will be able to act instantaneously, without hesitation. There is no time to think then. The enemy, if he is wise, will be forcing his passage at his utmost speed—one instant he is in danger from the torpedo, the next he may be safe—with the exception perhaps of a good shaking." His subsequent remark is worthy of being inscribed in letters of gold in every battery and every man-of-war:—"The great secret of the successful management of torpedoes will be found to consist in paying the utmost attention to apparently trifling precautions, and in trusting no one."

In the use of torpedoes, or in their actual application in the time of war, one of the most important lessons to be learnt is their planting. Great judgment and care are essential here, and it forms naturally an important feature in all courses of torpedo instruction. In referring to the difficulties of this operation, Captain Fisher has pointed out that it is of the utmost importance in laying down a torpedo to insure the preservation of its exact position; to avoid any chance of a fracture of the insulated wire through twisting; to calculate accurately the exact height and force of the tide, so as not to expose the torpedo at low water, nor make it inoperative at high; and to consider carefully currents, winds, the action of spring tides, and any other exceptional points in the channel under protection. Position also requires great consideration and experience; for it is quite possible to lay down scores of torpedoes which would be perfectly useless. For instance, it is essential to plant them at such a distance from the line of coast under protection as to prevent ships from coming sufficiently near to use their guns effectively. It is also important to plant them, like lettuces or cabbages, sufficiently far apart from one another not to interfere with independent action. Reference has been made recently to the valuable aid to be derived from the *camera obscura;* but this instrument,

useful as it is, has been rather overrated, for its accuracy in daytime is difficult to insure except in peculiar circumstances, and at night it would naturally be useless.

But while the difficulty in using the electrical torpedo is chiefly technical or mechanical, and can be overcome by practice, the treatment of torpedoes to be used at sea, whether in the "spur" or "Whitehead" form, calls not only for technical skill and dexterity, but for personal qualities of the highest order. The "spur" torpedo is intended to be used in the new Thorneycroft boats, such as the Lightning. The object of these boats is, by the attainment of a speed of twenty or twenty-five miles an hour, to attack any man-of-war by coming up with it, launching against it a torpedo, and then running away again. Simple as this operation may seem, it is attended with such manifest danger as to prove that special qualities of nerve and readiness are requisite. To use a torpedo in this way efficiently, it is important to be very careful both as to the place and mode of using it. As failure will, almost inevitably, prove fatal, constant practice is necessary to attain the necessary proficiency. In fact, to be successful demands on the part of the officer chosen for this work an amount of nerve and of delicate judgment not exceeded in any other warlike operation. The great recommendation about this mode of using torpedoes is that, if successful, its success is undoubted. The case of the Housatonic, mentioned by Mr. Donaldson at the United Service Institution, is a case in point. But precision in attack is absolutely essential. It is quite possible, as has been proved by experiment, to explode a torpedo harmlessly, although in actual contact with a ship's side. In one case the charge was submerged only six feet, and although the charge consisted of fifty pounds of powder, no vital injury was done. To quote Captain Fisher on this point—"The vertical effect of a submarine charge, no matter at what depth, is much greater than that in any other direction; this is but natural. The explosion is dammed up laterally, stopped by the bottom, reacted upon laterally, reacted upon by the bottom; so it is evident the greatest effect must take place in a vertical direction. The principle should always be borne in mind when endeavoring to attack an enemy's vessel with outrigger torpedo boats." He quotes an instance, the case of the Albemarle, where "the torpedo was submerged ten feet, and exploded under an overhanging portion of her stern, which, though several feet from, yet was virtually over, the torpedo."

Although this subject admits of much elaboration, and a great deal remains to be said about the special danger of the Whitehead torpedo, not only in its actual use, but in the mere fact of carrying such a destructive weapon in a man-of-war, we have said enough to show that there are two sides to the torpedo question. The torpedo is a very double-edged tool, and, valuable as its powers are for attack, its value depends mainly on the exercise of exceptional and high qualities.—*The Times.*

Captain Morgan Singer, of the Vesuvius, torpedo ship, has been carrying out a series of experiments in the capacious repairing basin at Portsmouth, with the object of discovering the best means of defending ships against the attack of the Whitehead torpedo. Up to the present time the ingenuity of the naval architect has been mainly exercised to protect ships against the entrance of shot and shell; and while for this purpose he has gone on increasing the thickness of the side armor, the bottom of the ship, against which the attack of the torpedo is directed, remains in almost its original weakness. How to protect the hull against both the gun and the torpedo and at the same time preserve the seaworthiness of the ship is one of the many problems in naval construction which have yet to be solved. In the meantime two methods of protection against torpedoes are proposed—viz., the employment of fast "satellites" to ward off and attack the torpedo boats before they can get within range, and the erection of crinoline frames around the ships themselves, by means of which the rush of the projectile would be arrested before striking the hull. Both devices have their disadvantages. The general use of patrolling craft would immensely complicate the exigencies of an engagement by provoking a number of subsidiary battles around the main action; besides, the

champions of these small craft seem to forget the all-important fact that in the next naval engagement the principal antagonists would themselves use the torpedo. Hence, even with the adoption of an auxiliary fleet, it is essential that our ships of war should be fitted with some defence against this terrible submarine engine. The torpedo net will necessarily impede the way and obstruct the manœuvring of an ironclad, and, such being the case, the object of Captain Singer has been to ascertain the form of crinoline which would oppose the least resistance to the water and the most resistance to the torpedo. Various forms of nets, composed of alternate lines of bars and chains, have been tried, but the size and power of the missile have been so increased of late that it has been found that the torpedo nets of the Thunderer afford little or no protection. Last week a chain net, formed of chains 5-16ths of an inch thick, was easily perforated by the Whitehead. The great fault of the nets is their extreme rigidity, which opposes a solid wall to the impact of the torpedo, and the bars are consequently snapped. After many trials, however, very successful results have been obtained from a wire grummet, matting, composed of wire strands about half an inch in thickness rove into open meshes. It possesses considerable flexibility, and, as it yields when struck, the force of the torpedo is not suddenly, but gradually, arrested, and as it loses its momentum it is thrown back by the recoil of the mat. During the experiments a torpedo thus forced back twirled its tail off without inflicting any injury to the matting. This is the nearest approach to perfection which has yet been attained.

MOMENTUM AND VIS VIVA.

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II.

III. IMPACT OF ELASTIC BODIES.

In the formula deduced in the last section for the common velocity of two bodies after impact, one of them was supposed to be at rest before impact. In order to make the formula more general let us suppose both the bodies to be in motion, in the same direction, their centers of gravity being in the same line of motion, and suppose their velocities to be such that impact shall occur. Let M and M' be the masses of the bodies, and U and U' their respective velocities. Let M' be in advance of M; then in order that impact may occur, U must be greater than U'. In that case the mass M will overtake the mass M', and have its velocity reduced by the impact, while that of M' will be increased, until they acquire a common velocity. Let X represent that common velocity, or the velocity of the two bodies at the instant their velocities have become the same. Then, by a course of reasoning similar to that employed before, we shall have the proportion,

$$M : M' :: (X - U') : (U - X);$$

from which we get $X = \frac{MU + M'U'}{M + M'}$.

The common velocity is deduced without reference to the nature of the bodies, and is therefore the same for elastic as for inelastic bodies. The bodies would be compressed by the impact, and if perfectly inelastic would remain compressed, with no tendency to recover their form, and would move on with the common velocity. If they were elastic they would immediately tend to recover their form, and in so doing would re-act upon each other in such a way as to produce a further change of velocity in each; and they would separate, and neither of them retain the velocity X. In the impact of elastic bodies we therefore distinguish two periods of the action. In the first period the bodies are compressed, and acquire a common velocity, and in the second period they to a greater or less extent recover their form, and their velocities again become different.

A perfectly elastic body would be one which after compression should completely recover its form, and which should exert in the recovery of its form a force exactly equal in intensity, at corresponding points of the action, in the inverse order, to the force by which it was compressed. There are no known solids which are perfectly elastic. Physicists usually call the force with which bodies are compressed the *force of compression*, and the force with which they recover their form the *force of restitution;* and the ratio of these two forces, for the various common solids, has been determined by experiment. This ratio is called the *modulus of elasticity.*

If impact were produced between two perfectly elastic bodies a certain velocity would be destroyed or generated in each respectively during the first period of the impact, while the bodies were undergoing compression and acquiring a common velocity; and since they would be urged apart in the recovery of their form by a force correspondingly equal in intensity and duration to that exerted in the compression, each would suffer a further change of velocity during the second period of the impact, equal to the change produced during the period of compression. If the bodies were perfectly inelastic there would be no second period to the impact and no change of velocity in either from the action of a force of restitution. And it is obvious that with bodies partially elastic the ratio of the change of velocity effected in each body during the first period of the impact to that during the second period will depend on the degree of elasticity of the substances. This ratio is taken by physicists as equal to the modulus of elasticity. Whether that modulus is so determined that this is precisely correct in all cases, may perhaps admit of question; but for all the purposes of the present discussion we may consider it sufficiently accurate. This ratio or modulus is denoted by E. For perfect elasticity E would be equal to 1; for perfect inelasticity it would be equal to 0; and for all intermediate degrees of elasticity its value is between those limits.

Recurring to the case of the mass M' moving with the velocity U', followed in the same line by the mass M with the velocity U, greater than U', an expression has been found for their common velocity at the instant of greatest compression, or the close of the first period of the impact; and that common velocity has been denoted by X. The velocity which the mass M will have lost during this first period will then be represented by $(U-X)$; and the velocity which will have been imparted to M' in the same period will be represented by $(X-U')$. In the second period of the impact the force of restitution, from the elasticity of the bodies, will still further diminish the velocity of M and increase that of M'. The ratio of the velocities destroyed or produced in each body during the two periods being E, the subtraction from the velocity of M in the second period will be $E(U-X)$; and the additional velocity imparted to M' in the same period will be $E(X-U')$. Thus the total subtraction from the velocity of M, during both periods of the impact, will be

$$(U-X)+E(U-X);$$

and the total addition to the velocity of M' during the whole time of impact will in like manner be

$$(X-U')+E(X-U').$$

If we now denote the velocity of M after the bodies separate by V, and that of M' by V', we shall therefore have

$$V=U-(U-X)-E(U-X)$$
$$=X-E(U-X).$$
$$V'=U'+(X-U')+E(X-U')$$
$$=X+E(X-U').$$

If in these formulas we substitute the value of X previously obtained, we find after reduction,

$$V=\frac{MU+M'U'}{M+M'}-\frac{M'E(U-U').}{M+M'}$$
$$V'=\frac{MU+M'U'}{M+M'}+\frac{ME(U-U').}{M+M'}$$

If the mass M' were moving before impact in the direction towards M, instead of in the same direction, we should find the same formulas with the exception that the algebraic sign of U' would be changed throughout. If the mass M' were at rest before impact, U' would be equal to 0. The latter part of this demonstration mainly corresponds to that given in Silliman's Physics.

From the above formulas, if we know the masses of the two bodies, their velocities before impact, and the value of E, we can easily determine the respective velocities of the bodies after impact; and knowing their velocities we can then calculate the momentum and vis viva of each. Let us illustrate the use of the formulas, and the proper interpretation of the results, by the solution of a special example.

Suppose there be two cast-iron balls weighing respectively 32 1-6 pounds and 160 5-6 pounds. Their masses will be $M=1$, and $M'=5$. For simplicity suppose M' to be at rest, but free to move, and suppose M to strike it in the line of their centers with a velocity of 1,000 feet per second. We shall have $U=1{,}000$, and $U'=0$. Take the value of E for cast-iron at 0.73, as given in Silliman's Physics, and suppose the balls capable of enduring the shock without breaking. Then by substituting these values of M, M', U, U', and E, in the formulas for the value of V and V', we obtain after reduction

$$V=-441\tfrac{2}{3}. \qquad V'=288\tfrac{1}{3}.$$

The value of V being negative we infer correctly that the ball previously in motion with the velocity of 1,000 feet per second will recoil from the shock with the velocity of $441\frac{2}{3}$ feet per second in the direction opposite to that of its former motion. But its momentum, or the intensity of the constant pressure required to bring it to rest in one second will nevertheless be $441\frac{2}{3}\times 1 = 441\frac{2}{3}$ pounds. The value of V' being positive the ball previously at rest will move with the velocity of $288\frac{1}{3}$ feet per second in the direction of the motion of the first ball before impact. Its momentum will be $288\frac{1}{3}\times 5=1{,}441\frac{2}{3}$ pounds. The arithmetical sum of the momenta of the two balls after impact is therefore

$$441\tfrac{2}{3}+1{,}441\tfrac{2}{3}=1{,}883\tfrac{1}{3} \text{ pounds.}$$

But the momentum of the first ball before impact was only $MU=1{,}000$ pounds. If then momentum represents a quantity of motion, and if motion cannot be generated by the impact, how shall we account for this great increase of momentum? We should have to assert that since the mass M after impact moves in the direction opposite to its former motion, its quantity of motion is less than no motion at all, or is equivalent to the destruction of $441\frac{2}{3}$ units of motion, and must therefore be subtracted from the quantity of motion of the mass M'; thus leaving a quantity of motion in the two balls equal to 1,000. But although it may be true that two equal and opposite pressures on a body will destroy each other, so that the body shall remain at rest, it is not true that the motion of two equal bodies with equal velocities in opposite directions is equivalent to the rest of either or both the bodies, or that their motion may be destroyed by acting on each other. Motion cannot be destroyed by the destruction of other motion. Whenever the motion of one body is destroyed, motion of one kind or another is *produced* in other bodies.

Take, for instance, two equal inelastic bodies moving towards each other with equal velocities. When they strike, they may apparently destroy each other's motion, but in fact the motion of neither is destroyed except by conversion into motion of another kind, viz: heat. And if all the work which could be performed by this heat could be applied to the double mass in one direction, it would give it a velocity just equal to that of either body before impact. Besides, there are many ways in which the direction of motion may be changed without material loss of velocity. Suppose the mass M in the above example after the recoil to strike perpendicularly a fixed elastic spring. It will be thrown back again in the direction of its first motion with a little loss of velocity. And then even the algebraic momentum of the two balls would have been increased by more than half the momentum of M before impact. And yet the velocity and momentum of both the balls in the same direction would be wholly due to the primitive velocity of the first ball. Or the direction of the motion of M may be reversed by allowing the ball to describe a semi-circular arc in a rigid groove, or to ascend an inclined plane till the force of gravity causes it to return. Or, if we suppose the bodies to be moving horizontally, their motion might be applied, by means of pulleys or otherwise, so as to raise vertically just as great a weight and to just as great a height as though they were moving in the same

direction. Has the mass M then less than no motion at all?

It would seem impossible to get clear of confusion in this subject, without discarding entirely the expression *quantity of motion*, and confining the term *momentum* to its exact meaning. The definition of momentum as a *quantity of motion* can only lead to absurdity, as we have already seen. But that definition is so widely accepted, and supported by such high authority that it may be worth while to sift it a little further.

Take the case considered above, the mass $M=1$, its velocity $=1{,}000$, and suppose that its quantity of motion is then equal to 1,000 of something, (who can tell what?) It should seem evident that a body cannot impart to another body more of a quantity of motion than it possesses itself. But yet, if the quantity of motion of M be equal to 1,000, we must allow that it imparts to M' a quantity of motion equal to $1{,}441\frac{2}{3}$; and this is absurd.

Again, if two bodies have no motion they must be at rest. But suppose we have two equal bodies M and M, moving in opposite directions with equal velocities V and V. Then if MV equals the actual quantity of motion of each, and if a quantity of motion in one direction destroys an equal quantity in the other direction, the total quantity of motion in the two bodies is $MV-MV=0$. Therefore the bodies have no motion, and hence must be at rest. But this is false, since they were supposed to be in motion.

This argument may be absurd, but we are inevitably led into all sorts of such absurdities if we attempt to consider momentum as a quantity of motion, or anything but what it really is. But with the correct understanding everything is perfectly clear and simple.

In the example we have now considered, one of the bodies was supposed to be at rest; but aside from that there was nothing peculiar about the conditions. And we found that after impact the arithmetical difference between the momenta, or, if you please (since the balls would be moving in opposite directions), the algebraic sum of the momenta of the two balls, was just equal to the momentum of the mass M before impact. Hence we might infer in general, that whatever the elasticity or masses or velocities of the bodies, the algebraic sum of the momenta after impact would be equal to that before impact; or that if the two bodies were moving before impact in the same direction, and after impact in opposite directions, the arithmetical difference of their momenta after impact would be equal to the sum of their momenta before impact. But we may give a general demonstration of this, which will not only prove it true, but will also show us why it should be true.

The masses of the two bodies being M and M', their respective velocities before impact being U and U', and after impact V and V', the change of velocity which the mass M experiences by the impact is $(U-V)$; and the change produced in the velocity of M' is $(V'-U')$. Now whatever the relative masses or velocities, or the degree of elasticity of the bodies, or whatever heat or molecular motion may be developed in the impact, the total resultant pressure on M is at every instant through the whole time of the impact precisely equal to the opposite resultant pressure which is exerted on M'. The changes of velocity of the two bodies will therefore be to each other inversely as the masses. We thus get the proportion

$$M : M' :: (V'-U') : (U-V);$$

whence

$$M'(V'-U')=M(U-V);$$

from which we have

$$MV+M'V'=MU+M'U';$$

in which the two members represent the algebraic sums of the momenta respectively after and before impact.

This last equation is derived in some works on Physics, by transforming and combining the general values for V and V' after impact. And upon the evidence of this equation the assertion is founded, that *by the impact of bodies, whether elastic or otherwise, no motion is lost.* But the equation does not prove that by any means. It simply proves that the algebraic sums of the momenta before and after impact are equal. And even that must be taken with a clear view of the circumstances of the case. For instance, in the example already solved, we found that the mass M would have a velocity after impact of $441\frac{2}{3}$ feet

per second in the direction opposite to its previous motion. You may say, if you please, that it has a negative momentum equal to 441⅔ pounds, but you must not understand that this actually destroys an equal part of the momentum of M'; for the bodies are supposed to have no connection with each other after impact. All we can say is that if the momentum of M *could* be applied so as to destroy an equal part of the momentum of M', the remaining momentum of M' would be equal to the momentum of M before impact. But this does not prove that there is no motion lost. For in our example the bodies are partially inelastic, and in the impact there must have been more or less change from ordinary motion to heat; and we shall find further on, that the heat developed by this case of impact, if equally distributed through the two balls, whose combined weight is 193 pounds, would raise the temperature of the whole mass 11.4784 degrees Fahrenheit. Has there then been no destruction of motion? True enough, there may not have been, if you consider this heat as motion. But then, the momentum after impact entirely neglects this motion, and yet comes out algebraically equal to the momentum before impact, and arithmetically much greater still. Can it then in any way represent motion?

If, however, we make momentum what it is, there is no difficulty in seeing why it should in every case be algebraically equal before and after impact, and why in some cases it may be arithmetically much greater after than before. For it follows from the continual equality and opposition of the resultant pressures on the two bodies for the same length of time, that the changes of velocity are inversely as the masses, and thus that the algebraic addition to the momentum of the one is equal to the algebraic subtraction from the momentum of the other, and hence the algebraic sum of the momenta cannot be altered by the impact, whether the bodies are elastic or not. But if, as in the above example, the degree of elasticity and the relative velocities and masses of the bodies are such that in the second period of impact the force of restitution entirely destroys the velocity of M in its former direction and gives it a new velocity in the opposite direction, then the algebraic sum of the momenta after impact means the arithmetical difference of those momenta; and of course the actual or arithmetical sum of the momenta after impact must therefore in such case be greater than that before impact, by just twice the actual momentum of M in its new direction.

We need not be afraid of the fact that it is possible to have an actual increase of momentum by impact. For we found that with perfectly inelastic substances, whatever change there might be from ordinary motion to heat, the momentum would be the same after impact as before. Now if a very small mass with a high velocity impinge on a very large mass at rest, when their velocity becomes common it will be very small; and then if the bodies are elastic and the force of restitution operates to separate the bodies and change molecular motion back into ordinary motion, at the instant the velocity of the small mass becomes zero the momentum of the large mass will be equal to that of the small mass before impact; then if the force of restitution has not finished its work a new velocity will be given to the small mass in the opposite direction, and the momentum of the large mass will be still further increased by exactly the momentum given to the small mass in the new direction.

It may also help us to see how actual momentum could be increased by impact, to consider the following proposition, viz: *Of two unequal masses moving with such unequal velocities that the vis viva of the one is equal to the vis viva of the other, the momentum of the one which has the less velocity is the greater.* This may easily be demonstrated generally, but it will be sufficient to consider a single example. Let the mass M have a velocity of 1,000 feet per second, and let M'' be another larger mass such that when moving with a velocity of 500 feet per second its vis viva, or the work which it can perform, shall be equal to the vis viva of M. The momentum of each mass is the constant pressure which can bring it to rest in one second. But if the mass M be brought to rest by a constant pressure in one second, we know from the laws of uniformly retarded motion that it will move through 500 feet in coming to rest. And the

mass M'' in coming to rest in the same way would move through 250 feet. Therefore if the mass M'' performs the same amount of work in passing through 250 feet, as the mass M performs in moving 500 feet, the intensity of the pressure exerted by M'', or its momentum, must be twice that of the mass M. The same may be shown by comparing the expressions for the momenta of the two bodies; for under the supposition M'' would be four times as great as M, with half its velocity.

If then, all the power of a moving body could be applied to give a larger mass a less velocity, with no loss of vis viva from the development of molecular motion, the momentum of the larger mass would very properly be greater than that of the mass from which it was derived. But from the nature of the case, in the impact of two bodies, whether elastic or not, whatever molecular motion is once developed cannot be re-converted into ordinary motion without the bodies can re-act on each other so as to be driven apart and move relatively in opposite directions. Thus the algebraic momentum cannot be increased by the impact, although in many cases, as in our example, a body at rest may acquire from a moving body a greater momentum than that of the moving body itself, and thus the actual arithmetical momentum of the two may be very much larger after than before impact.

Let us now resume the case of the two cast-iron balls, and calculate the vis viva of each after impact. The vis viva of M will be

$\frac{1}{2}\times(-441\frac{2}{3})^2=97{,}534.722$ foot-pounds.

The vis viva of M' will be

$\frac{1}{2}\times 5\times(288\frac{1}{3})^2=207{,}840.278$ foot-pounds.

Now we could with just as good reason say that the actual total of the vis viva of the two balls after impact is equal to the arithmetical difference between these values, as that the actual total of the momentum is equal to the arithmetical difference of the momenta; for the work represented by the vis viva will be performed in the same direction in which the momentum would be exerted. But it so happens, by squaring the velocity of M, that whether we consider that velocity positive or negative, the vis viva of M is algebraically positive. In treating of momentum and vis viva, then, in connection with impact, a negative sign of the velocity in the result should be regarded simply as showing the direction of motion, and should not be blindly taken as indicating destruction of motion, or anythind of the kind.

Remembering, then, that after impact, the two balls move in opposite directions, we may still say that the total vis viva, or work which they can perform, is equal to the arithmetical sum of the two parts, or 305,375 foot-pounds. Now the vis viva of the mass M before impact was

$\frac{1}{2}MU^2=\frac{1}{2}(1{,}000)^2=500{,}000$ foot-pounds.

Hence the loss of vis viva by the impact, or the work employed in the development of heat is 194,625 foot-pounds, or considerably more than one-third of the whole vis viva of M before impact.

To determine the increase of temperature of the two balls, supposing the heat developed were uniformly distributed through their mass, we have the weight of the two masses given=193 pounds, the mechanical work consumed =194,625 foot-pounds, and the specific heat of iron=0.1138. Now the expenditure of 772 foot-pounds of work in developing heat is capable of raising the temperature of one pound of water one degree Fahrenheit; hence the same work will raise the temperature of one pound of iron $\frac{1}{0.1138}$ degrees, or of 193 pounds of iron $\frac{1}{193\times 0.1138}$ degrees. Therefore the rise of temperature of the two balls, from the consumption of 194,625 foot-pounds of work would be

$$\frac{194{,}625}{772\times 193\times 0.1138}=11.4784 \text{ degrees.}$$

To recapitulate, then, the accumulated energy of a mass of iron weighing 32 1-6 pounds, and containing therefore 1 unit of mass, moving with the velocity of 1,000 feet per second, and having accordingly a momentum equal to 1,000 pounds, would be capable of imparting to a mass weighing 160 5-6 pounds such a velocity that its momentum should be $1{,}441\frac{2}{3}$ pounds, and of giving to the first mass a velocity in the opposite direction such that its momentum should be equal

to 441⅔ pounds, besides developing heat enough to raise the temperature of 193 pounds of iron through about 11½ degrees Fahrenheit.

One or two general conclusions, commonly unnoticed in the books, still remain to be considered. We found in the special example above that after impact the total *vis viva*, both arithmetical and algebraic, was less than before. And this would be found true in every case of impact unless the bodies were perfectly elastic. But if we had supposed the balls perfectly elastic, making $E=1$, we should have found after impact, $V=-666\frac{2}{3}$, $V'=333\frac{1}{3}$, and $\frac{1}{2}MV^2+\frac{1}{2}M'V'^2=500{,}000$, which is equal to the vis viva before impact. And if, in the general equations for the values of V and V' after impact, we make $E=1$, square each of the equations, and multiply both members of the first resulting equation by $\frac{1}{2}M$, and both members of the second by $\frac{1}{2}M'$, then add these equations member to member, and reduce, we shall find this equation,

$$\tfrac{1}{2}MV^2+\tfrac{1}{2}M'V'^2=\tfrac{1}{2}MU^2+\tfrac{1}{2}M'U'^2;$$

which proves that *in every supposable case of direct impact of two perfectly elastic bodies the total vis viva after impact would be equal to the total vis viva before impact.* There would then be no heat remaining as the result of impact.

In the second section it was found that when one body in motion strikes another body at rest there is more "work" performed in reducing the velocity of the former than in imparting velocity to the latter; otherwise there would be no loss of vis viva by impact. This loss of vis viva was accounted for by the equivalent of heat developed. But the question then arises: If the total resultant pressure which reduces the velocity of one body is continually equal to the total resultant pressure which increases the velocity of the other body, the two bodies being in contact, how can there be more work performed in the one case than in the other? The explanation, however, is not difficult. For we have seen that in all cases of impact the bodies are compressed; and this compression will bring the centers of gravity of the two bodies closer together at the moment of greatest compression than at the first instant of contact. If then a body in motion strikes a body at rest, or moving more slowly in the same direction, during the period from the instant of contact to that of greatest compression, the foremost as a mass, or its center of gravity, must move through a less distance than the mass, or center of gravity, of the other. Therefore, since the resultant pressures which change the velocities of the masses are constantly equal, but exerted through different distances, it is a necessary result that the quantities of work performed are different. If now the bodies are elastic, and the ratio of their masses within certain limits, during the second period of impact the case will be reversed and more work will be performed in imparting velocity to the foremost body than in retarding the other, since by the separation of their centers of gravity the mass of the former moves through a greater distance than that of the latter.

A consideration of the relative distances passed through by the centers of gravity of the masses leads to a rather interesting result, as follows:

Assume the conditions and notation adopted at the beginning of the third section, and we have the proportion

$$M : M' :: (X-U') : (U-X),$$

whence,

$$M(U-X)=M'(X-U').$$

Multiplying both members by

$$\tfrac{1}{2}(U+X)(X+U')$$

we obtain

$$\tfrac{1}{2}M(U^2-X^2)(X+U') = \tfrac{1}{2}M'(X^2-U'^2)(U+X),$$

whence the proportion

$$\tfrac{1}{2}M(U^2-X^2) : \tfrac{1}{2}M'(X^2-U'^2) :: (U+X) : X+U').$$

The first term of this proportion represents the number of units of work required to reduce the velocity of M from U to X, and the second term the work required to increase the velocity of M' from U' to X. Now if we let D represent the distance passed through by the center of gravity of the mass M while suffering the reduction of velocity from U to X, and D' the distance passed through by the center of gravity of M' while having its velocity increased from U' to X, then, since the work employed in producing these changes of velocity

is performed by resultant pressures constantly equal, the quantities of work will be to each other as the distances; thus giving the proportion

$$\tfrac{1}{2}M(U^2-X^2) : \tfrac{1}{2}M'(X^2-U'^2) :: D : D'.$$

Combining this proportion with the last one obtained above, we have,

$$D' : D :: (U+X) : (X+U');$$

or, if T represents the time from the instant of contact to that of greatest compression,

$$D : D' :: \tfrac{1}{2}T(U+X) : \tfrac{1}{2}T(X+U').$$

Now $\frac{1}{2}T(U+X)$ is the distance through which the center of gravity of the mass M would pass in the time T, if its velocity were reduced with a perfectly uniform retardation, from U to X; and $\frac{1}{2}T(X+U')$ is the distance through which the center of gravity of M' would move in the time T, if its acceleration from U' to X were also perfectly uniform. The actual distances D and D' passed through by the centers of gravity of the two bodies in the time T are therefore to each other in the same ratio as if the center of gravity of the mass M were uniformly retarded and that of M' uniformly accelerated during the time T.

Before concluding this discussion perhaps a word or two further should be said as to the product $\frac{1}{2}MV^2$, to which the name *vis viva* has been given. Some authors apply the expression *vis viva* to the product MV^2, or to *twice* the quantity of work which a moving body can perform. Now we might of course, if we chose, by common consent, give the name *vis viva* to the product MV^2; but if we consider the meaning of the name, (*living force*), there would seem to be much better reason for applying it to $\frac{1}{2}MV^2$, which is the *actual* quantity of work the body can perform by parting with all its velocity. This application of the name does not alter the fact that the vis viva *varies* as the mass into the square of the velocity. Besides, we seem to have the best authority of all, that of the originator of the name, for adopting this use of it. Professor Cooke, (Chem. Phys., p. 53), states that the product "$\frac{1}{2}MV^2$ was named by Leibnitz *vis viva*, or *living force*;" and the fitness of this designation has been already sufficiently shown.

We may now take a brief review of the claims of momentum to be considered the *quantity of motion* of a moving body, and also of the true claims of *vis viva*. We have seen, first, that the unit of momentum is simply a pound pressure, a unit which does not include the idea of motion; whereas the unit of vis viva is a pound pressure exerted through a distance of one foot, a unit which does include the idea of motion. Secondly, we have seen that momentum is not an effect that a moving body *necessarily* produces, but is only a special result under arbitrary conditions, generally impossible to fulfill; whereas the vis viva represents a definite stored up energy which *must* be put forth under whatever circumstances the motion of a body is destroyed. Also, if we would make a proper distinction between the *living force* of a moving body, or the work it can perform, and the *striking force*, understanding by this the mean intensity of pressure the body would exert when brought to rest in any distance, the momentum would be merely one case of the striking force, found by dividing the vis viva, or $\frac{1}{2}MV^2$, by $\frac{1}{2}V$, or the distance the body would move if brought to rest by a constant force in one second. Thirdly, we have seen in case of impact, that however great the change may be from ordinary motion to molecular motion, momentum is never diminished, and in many cases may be actually increased; and these conditions could not obtain if momentum in any way represented ordinary motion; whereas if the bodies are in the least degree inelastic, so that there is any change from ordinary motion to molecular motion, vis viva is correspondingly diminished, indicating its close connection with ordinary motion; and vis viva can only remain undiminished by impact when there is no permanent change from ordinary to molecular motion. Finally, we have seen that the attempt to consider momentum as a quantity of motion is unphilosophical, unnecessary and pernicious, and leads to manifold absurdities; whereas, *vis viva*, or $\frac{1}{2}MV^2$, truly represents a moving body's accumulated or potential energy for moving against resistance, or producing motion in other bodies by parting with velocity of its own.

ON THE PRIMING OF STEAM BOILERS.*

By Mr. WILLIAM MAJOR.

From "The Engineer."

It is certainly humiliating for the profession to be obliged to admit that one hundred years after the introduction of the steam engine they are still unable to subdue an evil so generally experienced as the priming of steam boilers; yet such is the case, as proved by the Serapis. The first question to be solved is: What is the cause of priming in a steam boiler? and until this question is satisfactorily answered engineers will still go on devising mechanical contrivances for obviating it, and their efforts will end in as many signal failures as hitherto. If we ask a practical engineer what the cause of priming is, we generally have dirty water assigned as a reason, and a specific is given for its prevention; or, what is more usual since the more general introduction of high pressure steam boilers, some remarks not very complimentary to the constructor of the boilers of which he may have charge and the priming of which he is unable to master. If we ask the same question of a scientific man—a professor of chemistry for example—he will answer that priming is ebullition caused by the action of heat on the body of water contained in the boiler, but he is not quite certain as to whether this so-called ebullition is a chemical or a mechanical action. With this meagre information the profession has had to content itself, enduring at the same time all the evils attendant thereon.

In the case of the Serapis we have a ship engined with a power sufficient to propel her through the water with a speed of 13 knots an hour, but that engine power was so paralysed through the priming of the boilers that her speed was reduced to 9 knots. The case of the Serapis is by no means exceptional, the same evil obtains in a greater or less degree on board every steamship afloat, and the introduction of high pressure steam together with the surface condenser has very considerably increased the evil. Indeed, break-downs from large bodies of water passing with the steam from the boilers to the cylinders of the engine are daily occurrences, and more valuable steam engines are destroyed from this cause than from all other causes put together. The author need not enlarge further on the subject of priming and its consequences, but will observe that he feels assured of having discovered a better theory for the cause of priming in steam boilers than is yet generally known. He has also found a practical means of preventing the evil, and that too without putting shipowners to any expense, but on the contrary, since to stop priming is to save fuel. The author does not propose any costly or complicated machinery for the purpose of preventing priming, not even a wooden deck placed in the boiler, as it was stated was adopted in the Serapis' boilers. As before stated, the cause of priming is said to be ebullition in the body of water contained in the boiler caused by the heat acting on the water. The author is bold enough to alter the word "ebullition" into the more intelligible word "friction," and he ventures to assert that priming in steam boilers is—as nature's simple law ought long ago to have taught us—caused by friction on the outer surfaces of the steam globules as they pass up through the overlaying body of water into the steam chest, the amount of such friction being always in due ratio to the velocity at which they pass through the body of water, and also depending upon the state of the water as regards its purity. In other words, the friction is least when the water is pure—distilled—while it is the greatest when the water is charged with all the organic and inorganic matter it can hold in solution. The author is only now, after four years practical experience on a large scale, publicly making the above assertion, and with the full conviction of its correctness.

Having satisfied himself as to the feasibility of the friction theory, it occurred to him that we had mistaken the real effects or action of the old-fashioned

* A Paper read before the Society of Engineers.

system of injecting melted tallow into boilers for stopping their priming. The reason generally given why tallow or other fatty matter stops priming is because it spreads itself over the surface of the water and quiets it. The author, however, does not believe this is the case, since whenever there is a pressure of steam in a boiler, any fatty matter injected into it immediately diffuses itself throughout the whole contents of the boiler, both water and steam. That this is the case can be proved by simply drawing a glass of water from any part or height of a boiler charged with tallow or by condensing a portion of the steam. Both the taste and smell of tallow will be found in both cases. The author believes that fatty matter stops priming by lubricating the globules of steam as they pass through the overlaying body of water, reducing the friction on their surfaces, and, as a natural consequence, causing them to carry less water with them into the steam chest. So long as we continue to supply a boiler with a sufficient quantity of fatty matter, priming will not take place. But it so happens that we cannot use the quantity of tallow, nor indeed of any other ordinary fatty matter necessary for the purpose, without producing other evils which it is difficult, or even impossible, to contend with, at the same time the expense of their use would be greater than most shipowners would like to bear. Tallow contains so much insoluble matter, that if used in the required quantity it would soon choke the boiler up, while both animal and vegetable oils contain so much gummy or resinous matter they would soon cause evil effects on the interior of boilers if large quantities were used. Of all the patent compositions the author has seen or heard of, he has found none that will answer the purpose —at any rate neither for marine nor for locomotive purposes, simply because the chief cause of priming—impurities in the water—is never absent. Therefore what is required is a constant supply of the proper lubricating matter to prevent the baneful action of these impurities on the globules of steam as they are generated. For marine boilers in particular, too great a stress cannot possibly be laid on the simple fact that the cause of priming is never absent so long as the boiler is in use, or supplying the engine with steam, because the water pumped into the boilers always contains either organic or inorganic matter. And this is the case whether the engines are or are not fitted with surface condensers. If the engine is fitted with surface condensers, priming will in most cases be more severe than with the injection condenser, because the action of heat on the metal plates of the boiler is more intense where there is little or no lime on the plates, as with a boiler fed from a surface condenser, than from an injection condenser, where the water is constantly being changed, leaving all its organic and inorganic contents, with the exception of common salt, in the boiler. Consequently a constant supply of fatty matter is absolutely necessary to counteract the friction caused by these impurities.

The author has tried all the oils in common use, together with most of the patent compositions, for the purpose of preventing priming. He has always succeeded in the object sought, but has found them all impracticable when used in large quantities, or constantly supplied to a boiler. The only exception to this rule has been the application of petroleum. The purest rectified petroleum has not only prevented all priming, but has prevented corrosion and removed incrustations arising both from organic and inorganic impurities, and from oxidation of metals as regards the interior of the boilers, as well as of the engines themselves. It would, indeed, appear that by using sufficient petroleum to lubricate the steam globules as they are generated, the preservation of the steam boiler and engine is insured so far as their interiors are concerned. The author has not found that petroleum, pumped into the boilers with the feed-water, has had any injurious effect on india-rubber valves in or about the air pumps, though he has used it in large quantities for several months in succession. In the feed pumps, however, where petroleum, nearly in its pure state, comes in direct contact with the valves, india-rubber cannot be used for them. The advantages attained by the use of sufficient petroleum to prevent the priming of steam boilers have been found by the author to be :

(1) The prevention of priming, or, in

other words, preventing large bodies of water from passing over with the volume of steam from the boiler to the engine.

(2) The prevention of the injurious effects produced by water passing with the steam into the cylinders of the engine.

(3) A great reduction in the quantity of feed-water necessary to produce the required volume of steam, or, in other words, an augmented boiler steaming power in proportion to the smaller quantity of water required to produce the steam required, or a saving of fuel proportionate to the smaller quantity of water necessary for producing a given volume of steam, together with the reduced power required for lifting water for condensing dry steam as against that necessary for the condensation of saturated steam. To these must be added the saving of the power absorbed in overcoming the resistance of water in the ends of the cylinders when working with saturated steam.

(4) Augmented boiler steaming power when working with injection condenser, by the total absence of incrustation or corrosion.

(5) Prevention of rust, corrosion on the interior of the engine, together with the advantage of keeping the interiors of surface condensers perfectly clean without any other help.

(6) Its instantaneous action on any disturbance in the water in the boilers, which is one of its greatest advantages.

(7) The increased durability of both boiler and engines.

The disadvantage of using petroleum in an engine-room—for there is one disadvantage—is that petroleum is a combustible article which requires care in use. It ignites at a lower temperature than common oils, but with ordinary care, and keeping it out of contact with cotton or woolen stuffs the danger of its use in engine rooms is reduced to the same extent as that of its use in dwellings. It is, indeed, reduced to a far greater extent when it is stored in a fixed iron tank with but one opening on top for filling and connecting a suction pipe to the feed-pump of the engine. The danger is then reduced to the bringing of it to the tank. Petroleum will not ignite or burn in a closed vessel; a bar of red hot iron inserted into a closed cistern full of petroleum will not ignite it, because there is not sufficient atmospheric air for combustion. The author knows of no other danger or disadvantage in its use, and when this one disadvantage is put against the many advantages, and when it is considered that its use prevents marine engines from becoming paralysed, as but too often is the case at most critical moments, no practical engineer will, it is thought, differ from the author in the opinion that it will be wise to promote its general use.

In applying petroleum to boilers the author has constructed a combined valve and cock. This contrivance is screwed into the valve box of the feed pump between the suction and delivery valves, the safety cistern containing the petroleum, being placed in a convenient part of the engine-room. As the connection pipe is inserted through the top of the cistern, while no other cocks or connections on cistern are allowed, no danger can ever arise from inadvertence on the part of the men in the engine-room. This valve and cock is all that is required in addition to what is generally found in well-constructed steam engines—namely, a cock on the suction pipe, or a screw on the top of the suction valve of the feed pump, one of these being required for regulating the flow of water to the pump necessary for generating the volume of steam required, and the prevention of waste of petroleum, since any overplus of water the pump takes, and which does not pass into the boiler, is returned through the safety valve on the pump. The author has in practice regulated the water flow to the pump, so as to approach as nearly as possible the consumption in the boilers, leaving the feed cocks full open. This has given two advantages: First, no petroleum was wasted; and, secondly, it has directly shown when the steam was taking an undue quantity of water with it. That it is in the boiler itself that priming must be prevented appears evident, and it is equally evident to the author that all the mechanical devices for the purpose of preventing it have, for the want of the proper knowledge of the cause of priming, signally failed. Some of these devices—the superheater, for example, which is still in general use—are very complicated, and consequently very expensive.

The valve and cock, applied to insure instantaneous action, must have the necessary dimensions in proportion to heating surface in boilers it is intended to supply with petroleum. On starting the engines, or when forcing the fires, priming is generally most violent, and at such times the engineer's immediate attention is necessary, and he will act wisely in giving his boilers a little petroleum previous to forcing the fires. On a voyage from Copenhagen to St. Petersburg and back, with his Danish Majesty's steam yacht Slesvig, last summer, nearly 144 hours' steaming, the author consumed nearly forty gallons of petroleum, and this gave a gain of twenty-five tons of coal, as compared with what the same boilers and engines had previously consumed on the same journey in about an equal number of hours, namely 150 instead of 175 tons of coal. The ship, however, was drawing 2 inches more water last year than formerly, which increased her immersed midship section from 219 to 224.7 square feet, or $4\frac{3}{4}$ square feet nearly. There was, besides, the disadvantage of being in company with a screw frigate, whose sailing powers far exceed in speed the Slesvig's steaming powers, so that the author was constantly either forcing or easing the engines to keep in position with the frigate, which caused a considerable waste of fuel. The Slesvig has a pair of Robert Napier's old-fashioned side-lever engines with open condensers, and of 240 nominal horse-power, but which the author is now enabled to work up to 620 indicated horse-power. With the same draught of water as now, about 9 feet 4 inches, her speed formerly never exceeded ten and a-quarter knots, and this speed was with difficulty maintained for any length of time, for the want of sufficient steam. Since the application of petroleum to the boilers, however, the speed has been increased to eleven knots, and this without any increase in the consumption of coal. The steaming power of the boilers has been increased so much that there is now more steam than the engines consume, while the engines themselves are working with less noise than formerly.

The author succeeded last summer in removing all corrosion and incrustation from the interior of the Slesvig's boilers, and they are now as clean as when they left the boiler maker's hands ten years ago. Petroleum dissolves both the lime incrustations and prevents rust corrosions when under steam pressure, while all the dissolved muddy matter can be blown out from the bottom of the boiler with the ordinary blow-off cock; the boiler requiring no other cleaning out, and consequently there are no stoppages for this purpose. It may be interesting if, before concluding his paper, the author places on record a circumstance which came under his observation last year respecting marine boilers in connection with surface condensers and the use of mineral oils.

When the surface condenser was introduced in connection with marine engines one of the advantages expected to be derived from it was the freeing boilers from incrustation, and thus increasing the evaporating powers of the boilers; the danger of collapse arising from overheated fire-box plates was to be removed. The surface condenser was intended to return to the boiler the water taken therefrom in the form of steam, and as this water could contain no organic or inorganic or earthy particles, it was very natural to suppose that no incrustation could be formed in boilers supplied with them. But one of the first discoveries made after the introduction of the surface condenser was that the boilers supplied from it corroded them to an alarming extent, so that in many instances such boilers were entirely destroyed after only two years' service. This circumstance prevented their coming into general use until about twelve or fourteen years ago, when it was discovered that the corrosive action was caused by metallic particles taken from the interior of the engine by the steam on its passage through it, and carried into the boiler, where they produced a galvanic action which oxidized the plates of the boiler. About the same time it was also discovered that sea-water contained the best non-conducting agent for preventing a galvanic action in the interior of the boilers, namely, its organic and inorganic contents. In fact, the same matters which had hitherto caused incrustation were now found necessary, in smaller quantities, to protect the boilers against oxidation. This protection is afforded

by changing the water in the boiler occasionally with water direct from the sea, which leaves a coating of its organic and inorganic contents on the interior surfaces of the boiler, and thereby insures safety from galvanic action, and permits the general use of the surface condenser with marine engines. We have, however, for several years past heard of the collapsing of fire-box plates where they have been in connection with surface condensers, and the opinion invariably given as to the cause of these accidents has been that there was either a want of strength in the construction to assist the steam pressure, or that there had been carelessness on the part of the attendants in not supplying the boiler with sufficient water. This, however, is a great mistake, as there are other causes equally as active in causing fire-box plates to collapse as those just named. One special cause came under the author's observation. About midsummer last year the screw steamship Conatio, of Flensborg, on her way from Cronstadt to an English port, was towed into Copenhagen harbor in a disabled state. The four fire-boxes of the boiler had collapsed. They appeared to have all given way at about the same time. The fireman, on opening the fire-doors, saw the crowns of the fire-boxes sinking, and the engineer immediately opened the smoke-box doors, and took other precautions for reducing the steam pressure, and thereby in all probability saved his own life and the lives of the rest of the engine-room crew. Upon reaching the port the boilers were examined. There was plenty of water in them, and everything else appeared to be in perfect order; yet, on emptying the boiler, the injured crown plates of all four fire-boxes afforded clear evidence of overheating—in fact, they had been red-hot, and this notwithstanding that there had been plenty of water in the boiler, and that there was but a trifling deposit. The only reasonable conjecture as to the cause of the accident was that on the collapsed plates was found a thin layer of ordinary boiler incrustation, not more than a twelfth of an inch thick, mixed with a dark substance, which proved on examination to be the insoluble residue of a mineral oil, which had been used for the purpose of lubricating the interior of the engines. The lubricator used was fixed on the side jacket of the high-pressure cylinder, and from thence the oil passed through the surface condenser to the boiler. This insoluble matter then mixed with the slight incrustation, and which, thin as it was, had been sufficient to make a perfectly impervious coating, which had prevented the contact of the water with the iron plates. Hence the overheating and collapsing of the crowns of the fire-boxes.

In the month of September last the author was requested by the Danish Board of Trade to survey and report upon the condition of a boiler on board a merchant steamship, the Bergen Huns of Copenhagen. This vessel came into port at Copenhagen with a boiler which had been disabled on the voyage from Norway to Stettin. Here was a similar case to that of the Conatio, only perhaps a little more decisive as regards the cause of the accident. The Bergen Huns is fitted with compound engines supplied with steam from a cylindrical boiler having two cylindrical fire-boxes in it, one of which collapsed. The fire-box collapsed eight inches in towards its center over a length of four feet six inches from the back end, not, as might be supposed, along a line drawn perpendicularly through its center, but at an angle of forty-five deg. with it towards the side of the ship. In this case the engineer, seeing there was no want of water in the boiler, ordered the fire to be drawn out of the collapsed fire-box and proceeded with the other fire on his voyage, and came in to Copenhagen some twenty hours afterwards. Such a piece of dangerous stupidity succeeded in his case, but has probably failed in too many others under such circumstances.

On examining the interior of this boiler the author found that half of it—namely, that side on which the feed-cock was fixed—was coated with a substance resembling black varnish or coal tar, having a thickness of about three-sixteenths of an inch and being perfectly impervious to water. This deposit had the appearance of having been laid on with a brush, so equally was it spread, particularly over the fire-box. It was under this coating of impervious matter the fire-box plate had collapsed, while the other fire-box remained uninjured,

notwithstanding that it had a coat of ordinary boiler incrustation ¼ inch thick. The incrustation on this side retained its ordinary grey color. On inquiring of the engineer from whence this black substance came, he stated that it was produced from the oil used to lubricate the slide valves with. He observed that he was obliged to use a great deal of the oil to keep the valves from making a noise and cutting their faces. The oil used for this purpose was a half crude mineral oil, which still retained so much of its original earthy bituminous constituents, that the latter, combining together with the organic and inorganic matter contained in the boiler, made a perfectly impervious cement which had prevented the contact of the water and iron, and being a bad conductor of heat, caused the iron to be over-heated, and thereby weakened, the steam pressure causing the collapse. The author laid a piece of this compound on a piece of iron heated to a little over red heat, which had, however, produced no further effect than the burning of a little of the bituminous matter out of it. The collapsed plate bore evidence of having been overheated, and it was only owing to the superior quality of the iron, of which the fire-boxes here as well as in the case of the Conatio were constructed, that a most serious loss of life had not taken place.

The reason why only one half of the boiler was coated with the bituminous matter, the author attributes to the circumstance that the injured side of the boiler had on it the feed-cock, and that as the oil, passing through the latter, came first in contact with the incrustation on that half, it was absorbed before it could reach the other side of the boiler. The uninjured fire-box, however, was coated with an incrustation ¼ inch thick over the whole of it. Now this thickness of incrustation ought never to be found in a boiler which is in connection with a surface condenser, and the fact of its being there clearly afforded evidence of the engineer's ignorance both of the use of the surface condenser and of the meaning of a trifling incrustation to preserve his boiler from galvanic action and oxidation. But, as seen in the case of the Conatio, the danger is not dependent alone upon the thickness of the coating of incrustation, but chiefly on its porosity. Let the incrustation be never so thin, a bituminous substance is added to it, which binds it together so that it becomes elastic and impervious to water; the iron plate will overheat and collapse under pressure. Hence, wherever oils containing bituminous matter are allowed to pass into a boiler, it is only a question of time as to when the incrustation becomes impervious, and the fire-box under it collapses.

The author was much surprised that the uninjured fire-box in the Bergen Huns boiler had not collapsed also, more particularly as the incrustation on it was spread very evenly and closely. In boilers working in connection with open injector condensers, incrustation attains a considerable thickness in places where it cannot easily fall off. But on a cylindrical fire-box it would undoubtedly never have laid so compactly as was the case here; it would have been broken and in uneven patches. It appeared evident that some of the oil had also reached the uninjured side of the boiler, and had acted on the incrustation there. The author, therefore, would recommend precautions being taken so as not to allow these oils to enter steam boilers. There is no necessity for their use at all; a little pure rectified petroleum pumped with the feed-water into the boiler will prevent such accidents as the collapsing of fire-boxes. It will be sufficient to lubricate the internal parts of the engines, and, at the same time, will keep the surface condensers perfectly clean.

Looking at the foregoing facts, the author thinks it will not be difficult to account for the disappearance of many missing steamships. At any rate, a careful investigation into the cause of this class of accidents is a matter of the greatest importance, and the author hopes the remarks he has made may have the effect of drawing attention to the subject.

Californian Ironstone.—An effort is now being made by a number of enterprising American gentlemen to open up vast deposits of ironstone, which are said to exist a few miles above Auburn, on the line of the Central Pacific Railroad.

MODERN EDUCATION.

By ALFRED P. BOLLER, C. E.

Commencement Address to Graduating Class of '77 at Rensselaer Polytechnic Institute.

Once more, in the sequence of events, the season of the year has arrived when the higher educational institutions throughout the land are all aglow with the excitement of "commencement day," while fathers and mothers await the hour, with proud satisfaction, when the coveted parchment, certifying to all manner of learning, will have been formally bestowed upon their representatives in the rising generation. Thenceforth, the diploma becomes a family heirloom, to be carefully stowed away in its japanned tin case among the family archives, or perchance hung upon the wall of the family sitting-room in a handsome frame, a daily reminder of what "our boy" has accomplished. Amid all the changes that have taken place in our educational systems, the practice of a public introduction to the world, of the completed product of such schools as confer degrees, is one that even the most radical iconoclast has not attacked. The commencement season is no meaningless formality, but an important epoch in the life of each generation as it passes along. It is at once the beginning and ending of a never-to-be-forgotten period of one's life. From the controlling influence of home and the instructor, the young man steps at this season into the arena of worldly strife, and thenceforth must bear the responsibilities of his own actions. Further than this, every graduating class adds just so many units to the world's educated intellectual forces, out of the clashing of which are evolved those ideas upon which the progress of humanity depends. Commencement day is therefore not alone a time of public congratulation for the honorable completion of a task, but a solemn occasion to signal the entering upon a new life of a class of young men, to whom is given a very important part to play in their country's development. As such it will always have an interest for society, the members of which will gather on all commencement occasions, year after year, as they have always done, not only paying a cheerful tribute to intellectual success, but also warmed up by that great under current of human sympathy, that makes life worth the living. Like the wedding day, commencement day will never lose its interest for society, but will stand as long as the school and college form the basis of our social well being. The laudable ambition to excel in educational advantages, has in recent years taken a firm hold of the American people, and countless schools and colleges have been established all over the Union. While some are the outgrowth of a pardonable vanity on the part of a wealthy donor, ambitious to perpetuate his name in a community out of which he sprung, the greater portion have been created in response to a demand for knowledge among the masses, impelled as it were by the exactions of increasing culture. Taking them altogether, they are evidence of a nation's effort toward intellectual advancement, and are a standing rebuke to those pessimists who love to dwell mournfully on the "degeneracy of the times." It is a matter for regret that so many of these newer colleges are weaklings, anticipating by years the capacity of the community in which they are situated to properly support. While giving every credit to the motives which founded them, they are costly evidences of the unwisdom, with which men of wealth, ambitious to serve the cause of education, often discharge their self-imposed stewardships. Had the same amount of wealth that has been scattered throughout the country in numberless higher class schools and colleges, that for years must have a very struggle for existence, been concentrated in well established educational centers, the benefit to the cause of sound learning, would necessarily have been very great, and it is to be hoped that future donors will add their benefactions to existing schools, rather than increase their number. The educational period through which we are passing, is in marked contrast to that which gave character to the generation now fading out of sight. This contrast

is sharply drawn, and it will be in harmony with this evening's celebration, to ask your attention to some of the leading features of the "new education"—what it has done for society, and what course its future development will probably take. In the first place it is to be remarked, that educational systems are not determined by purely human inspiration, but rather the result of certain social conditions, forming the soil, as it were, out of which grows that system which it is best capable of nourishing. The "*Novum Organum*" could no more have been a product of a barbarous society, than the rose a product of the desert. In all social movements it is impossible to determine the exact line of demarcation between two radically different systems, so imperceptibly does one merge into the other. We know when a change is complete, and we are struck by the contrast with that which it has displaced, but the ending of one, and the beginning of the other, cannot be defined. As in all things the new never displaces the old without a struggle, so the ideas of the new education have not won their well nigh universal acceptance without vigorous opposition from the old regime of school men. It is the story over again in a different shape of the "Revival of the Arts and Sciences" in the fifteenth century, when the supporters of the scholastic wisdom of the middle ages had to yield to the progressive culture of a newer school. That contention history has handed down to us as the struggle between the obscurantists and the humanists, apt terms, tersely embodying the distinctive qualities of each. The obscurantists of our day, what few of them are left, are represented by those who would base educational systems upon transmitted opinions, on metaphysics and the literature of bygone ages. With such nature is held up to the test of authority, and in case of disagreement, so much the worse for nature. On the other hand our modern humanists rupudiate authority as such, regard society and civilization as a development, and test all ideas and asserted truths, in the crucible of natural law and order. While the germs of the new system can be traced back through centuries, in a fitful sort of a way, it was not until the close of the sixteenth century, when Francis Bacon, whom Pope pronounces the "wisest" and "best" of mankind, despite his moral infirmities, gave to the world a system of logic, at once so profound, complete and penetrating that it marks an intellectual epoch, and formed the solid foundation of modern processes of reasoning. He expressed his disgust at the school methods then in vogue in these words: "They learn nothing at the universities but to believe. They are like a becalmed ship, they never move but by the wind of other men's breath, and have no oars of their own to steer withal." The whole key of Bacon's teachings embodied in the idea that all learning, all knowledge should have but one object—"the good of humanity." He held that study instead of employing itself on wearisome and sterile speculations, should be engaged in mastering the secrets of nature and life, and applying them to human use. Instead of hypotheses, he called for facts, and he showed that the only road to truth was by proceeding from effect to cause, thus utterly reversing the customary methods of mental training and culture. It so happened that the intellectual soil succeeding Bacon's time was ripe for just such seed, which has grown and expanded into a tree bearing fruit of abundant promise. The growth was slow at first, but the dropping of its blossoms from time to time rapidly reinvigorated the soil in which it had taken root, and to-day we see its overshadowing branches extending throughout all civilized nations. The tangible fruit of this "tree of knowledge" is *science*, the true meaning of which term it is important for us to bear in mind. As formerly used, it was applied to those branches of knowledge termed physical, and there are those even now who have no higher conception of its meaning. In the present and developing order of things, it has a much broader signification, and refers more to a certain method of investigation, than to specific subjects. Its scope embraces all fields of human research that are capable of being brought under general laws, based upon observed facts. Science aims to bring "thought in harmony with things," and whatever subject is traceable from effect to cause, by inductive processes, is a legitimate field for scientific investigation, be it religious,

social, political, or physical. The growing demand, on the part of the intelligent masses, for popularized science is due to the recent appreciation of this very broadened view of the meaning of science. So long as science was confined to the investigations of certain branches of purely physical interest, and taught as was done at our universities a quarter of a century ago, popular interest in it was rather of a sentimental kind. Science, however, when applied to higher problems, such as life, politics or religion, comes home to the thinking individual with transcendent power, and creates in him a very craving to know to what hitherto hidden Arcana, he is being conducted. As applied to education, the scientific method of investigation, as a system, is comparatively modern, and was the natural consequence of the discovery of the successful application of steam to practical uses, the opening era of the most stupendous advancement in things material, intellectual and moral, that the world has ever seen. None other could exist in a soil so prepared, and, as a consequence, we have seen the system based upon old university methods of scholasticism and tradition gradually fade away, until the bare bones are left, and even they are crumbling into the dust of antiquity out of which they sprung. The scientific system of education, the "new education," as it is sometimes called, is unassailable, in that it is a natural one, utterly untrammeled by reverence for the past, or devotion to a "school." It seeks nature before the study, and inculcates the acceptance of all truth based upon the facts of nature, as the only sure foundation of a progressive culture. It wars not with ideas, but with error, and is only intolerant of a refusal to accept truth regardless of consequences. It is impatient of shams of all kinds, and quickly pierces the shield of the charlatan. Jealousy, or a desire to restrict knowledge to a few, it is incapable of fostering, but on the contrary is aggressively active in disseminating information among the masses, which in turn produces a reflex action in the elevation of character and morals. The new system is but the legitimate evolution arising from social betterment, and none other than a "material age" could have supported its development. I am aware that this term "material," is often offensive to many well meaning people, but it is nevertheless true that the whole history of society, shows that all intellectual advancement is based upon certain material conditions. Food for the stomach, clothes for the back, and a cover for the head, are the individual's first needs. Due attainment of these in a greater or less degree is necessary before the receptivity of the mind is such as to appreciate the idea that man is two sided, intellectual as well as animal. The intellect, like the body, grows by what it feeds on, and if this food of which it partakes, consists of an active participation in the affairs of commerce, of mines, or manufacture, it is not to be wondered that its legitimate craving becomes a search after the facts and phenomena of nature, the proper appreciation of which is so essential to still higher social advancement. As civilization progresses, the luxuries of one age, imperceptibly become the necessities of the next, and any given generation would deem it a hardship to be compelled to return to the practices of their forefathers. The railway, steamship and telegraph have made the whole world kin, and year by year draw the nations of the earth together, through a community of interest and an enlargement of sympathy.

Before the age of steam, the experiences and observations of men, were limited to the narrow surroundings of their localities. Now the experiences of the world are brought to their feet, and they realize that so far from being independent factors in the guiding of events, they are so many units in the ocean of humanity, with a definite part to play in the scheme of development, and of an importance just in proportion to their power and wealth, both intellectual and material. Glorify the present as we will, we must not despise the past. There are names in antiquity associated with such commanding genius, and almost divine prescience, that they will live so long as literature is studied or science cherished. Emerson says, the "world has always been equal to itself," and take it at any part of its unquestioned history, it only has produced that which its intellectual soil and material condition was capable of nourishing. In the high-

est sense, the greatest triumph of science has been the reflex action upon culture and morals, as evinced in the emancipation of the minds of men from baneful superstitions, witchcraft, terrors of the untaught imagination, and a harmful reverence for tradition. Omens and auguries, long potent in influencing the actions of men, no longer hold sway, except among the ignorant and unlettered. Such mental fetters could not last under a system that teaches men that truth alone is worthy of study, to observe nature and follow her teachings. It is this contact with pure truth that elevates mankind, clears the head and purifies the heart. That broadens the sympathies until they take shape in efforts for the general amelioration of mankind, and inculcates the idea that the welfare of society is that of the individual. This spirit of science, which is truth, through self interest and sympathy, finds scope for expression in the building of hospitals, in the organizing of charities, in the improvement of laws, in the extension of the benefits of life insurance; in the elevation of the laborer, and in efforts towards adjusting his relations to his employer. The spirit of science is a great leveller of caste, teaches the equality of men before the law, and shows nations the conditions under which they can govern themselves without the intervention of kings. It has extended to woman control over her own property, and abolished slavery. The scientific spirit has taught people that disease is not a Providence, but neglect of the laws of health, only to be contended against by due observance thereof; that epidemics are preventible, and that rain will not fall without the necessary atmospheric conditions for its precipitation. Take all these reflex results of the new system of education, couple them with the direct physical pursuits of science, the improvement in the modes of living, of water supply, of drainage, the railway, the steamship and telegraph; and compare the result in their effect upon the one problem of life, "Human Happiness," with the best that can be said of the old regime of scholastic education. It is the comparison between the electric light and a candle.

What future developments science has in store for us, it would be rash to forecast with any attempt at details. We know that a vast amount remains to be done, so long as an ideal condition of society beckons us on. There is still an incalculable amount of want, and misery, and suffering, in the world; whole communities in ignorance, and many unadjusted questions between labor and capital. What is known as social science is just beginning to take form, and a host of problems growing out of it are to be worked out. The great work of the new educational system in the future will be the training of men to grapple scientifically with these social problems in all their complex relations, political and physical, and to sow broadcast among the people the idea of *causation*. That things proceed not by chance, but by law, that out of nothing, nothing comes, that there can be no effect without a cause, and that the operations of nature are conducted according to a system instituted when matter was formed and force originated. In physical matters, it is hardly probable that the world will ever see again such startling discoveries as those which have fallen to the lot of this century. The spirit of the "new education" will extend its benefits, and in the end carry them to people yet to be civilized. It will send out more workers in physical fields than ever before, but their work will consist in the development of details, and in the careful scrutiny of the by-paths that the past revolutionary discoveries, so to speak, have opened up. Of such work there will be an endless amount, indications of which are seen in the number of investigators in special lines of research, which from past experience we may expect will be sub-divided from time to time into still other special fields of study, as material accumulates. Civilized nations have insensibly adopted a system of divided labor, as a matter of economy partly, but principally because it has been forced upon them by the limitation of human powers. The system is not without its disadvantages, however, in that the specialist, devoted to one class of ideas, is apt to lose sight of the relativity of all knowledge, and to elevate into a fictitious importance the study he may have in hand. Like the aged German professor who had but one regret upon his death bed, and that was that he had

not been spared a few years longer to complete his investigations of the Greek particle α, to the study of which he had devoted his life. The most far-reaching consequence of the general acceptance of the scientific method of investigation, and the latter day broadening of its scope, is its effect upon such speculative and practical questions regarding life, as have profoundly interested men from earliest times. It is pretty plain to most thinking men, that the idea of intellectual freedom is spreading among cultured nations, and with it a broad humanitarian view of men's relations to each other. Under the light of science, old landmarks are being swept away with a remorseless hand, and doctrines and ideas that once seemed as unchangeable as the everlasting hills are being questioned with a penetrating earnestness. What were supposed to be historical facts are either discovered to be no facts at all, or must be so modified in their interpretation, as to have an entirely new significance. Opinions are formed more slowly now than of old, just in proportion as the amount of evidence to be weighed is so much greater now than then. History must be re-reviewed in the light of modern discoveries, which have followed each other during the last quarter of a century, so thick and fast, as to task the intellectual strength of a generation to arrange and classify in their scientific bearings. There are more gifted men than ever before, more specialists in every realm of human thought, and more searchers after truth, who, in all parts of the world, are accumulating facts and data, on which the generalizations of future philosophers are to be based. So far as new discoveries and methods bear upon material matters, our only interest is one of present use. We take a new idea to-day, only to throw it off to-morrow, for one better adapted to our needs, and so advance from day to day to greater prosperity and comfort. But when we come to estimate the effect of new ideas and discoveries upon speculative matters, and apply the modern scientific method of analysis by induction, we shrink from the iconoclasm thereby involved, and often deliberately shut our eyes with stubborn persistence, rather than contemplate for an instant the possibility of error in the cherished teachings of our youth, or in the convictions of mature age. This is perfectly human, is therefore natural, and should not involve the calling of hard names. Being natural, this tenacity in matters of opinion, or of convictions having all the force of truth, play an important part in the scheme of intellectual development, must be weighed as a factor thereof, and not treated simply as an obstinate superstitious phase of human nature to be banished by cynical sneers. Whatever may be the outcome of what may be termed an age of intellectual unrest, through which we are travelling, one thing we can take calm contentment in, and that is in the final exaltation of *truth*, which is the highest aim of science. That end may be a long way off, but so surely as all nature is subject to the law of development and change in some form so surely will some future generation attain the beatitude of perfect intellectual rest. If indeed we ourselves do not find it beyond the experiences of this life—the mysteries of which neither the chemist's crucible nor the biologist's microscope can solve.

Gentlemen of the graduating class, as a practising member of your chosen profession, I may be permitted to extend to you the welcome of fellowship. You have entered the profession of civil engineer at a time of peculiar depression in all matters pertaining to public works, railways and manufactures—and have added to the members of a profession full almost to overflowing. It must be admitted that purely professional practice has not a very encouraging outlook to those whose affiliations are not such as to have positions provided for them. In times of great public disaster, such as have followed the commercial world for the last four years, the engineer is the one to first feel the blow, and the last to recover in returning prosperity. His office is one of disbursement, which appears so directly on the expense side of the ledger, that it usually overshadows the indirect benefits with which it should be credited on the other side of the account. He would be a rash man to prophesy a new era of such prosperity as we thought we had previous to '73. How far this prosperity will prove to have been real, it is difficult to say, until all the loose ends are picked up, and the

balance sheet finally struck. Just at present, the civilized nations of the world are in possession of enormous productive capacities in all departments of manufactures, apparently far in excess of their respective markets. Transportation facilities seem to have fully kept pace with the manufacturing developments, and their extension at this time does not hold out a very enticing prospect to capital—at least in undertakings of any magnitude. It is hopeless to expect a speedy rectification of the lost equilibrium between supply and demand, or that it will be restored without further financial suffering. New markets must be sought in undeveloped countries, and population must increase to a greater or less extent to utilize what the United States, England, France and Germany, are now capable of producing. Until the balance is restored, prices will rule low, competition will be fierce, bankruptcies will be frequent, and capital will accumulate at financial centers in safe depositories, at low rates of interest. I must confess that the picture presented is not an encouraging one for the rising generation, but an early acceptance of the situation is certainly philosophical, if not agreeable. My object in alluding to such matters on this occasion, is to disabuse your minds of any ideas you may have formed of an early resumption of constructive activity in new works, which would give ample scope to your professional ambition; and further, to indicate the direction that I conceive to be the one where such an educational training as is given by the Rensselaer Institute will prove of value. I allude to the region of *economics*, the obtaining the most out of the least. In times of high prices, when prices are abnormally large, the idea of profit by saving is apt to be overlooked. On the other hand, when prices are low, the question of any profit at all, is a matter almost entirely of saving. The manufacturer, the merchant and transporter, are all asking themselves, *not*, how large a price they can charge for the commodities in which they deal, or for services rendered, but what is the lowest possible price for which such commodities or services can be afforded. Such questions involve a multitude of details, and it is just here where scientifically trained men have a large field before them. The economical organization of labor, the perfection of machines, the prevention or utilization of former waste, the rectification of past constructive blunders—are all questions of legitimate scientific study, which invested interests are rapidly recognizing. The economics of transportation, the management of railways and canals, are subjects that will repay the profoundest study, and in these directions the field for a brilliant professional reputation is most enticing. There are numberless vexed questions and unsolved problems in connection with transportation matters, that only scientific methods of thought, coupled with practical experience and observation, can grapple with. Ex-President Grant, is credited with the remark, that certain public men had the misfortune to begin their career as Major-Generals. There is a world of wisdom in the remark, no matter what its source, or to whom it applies. It is, indeed, a misfortune to rise in the world more rapidly than one's knowledge and experience warrant. Let me, as a matter of advice, caution you against the ambition of getting ahead too fast. All the schools in Christendom, cannot take the place of experience. They can at best, only prepare and furnish the mind, so as to make experience *scientifically* usable. It is, therefore, and in fact necessary, for a professional beginner to start low in the ranks, so that he may be familiar with the manner in which things are done, if he ever expects to take a high position in the command of men, and in the management of things. In other words, he must *know* how things are done, before he can *instruct* others to do them. In conclusion, let me remind you, that you go forth under the standard of an Alma Mater that has made a record in almost every state in the Union—see to it, that in your lives and practice, you honor her, as she this evening honors you.

American War Materiel.—Eight steamer cargoes of arms and ammunition have been shipped to Turkey from the United States. Five or six similar cargoes have gone by sailing vessels.—*Engineering.*

AN ACCOUNT OF AN EXCURSION ON THE MARNE RIVER, INCLUDING A DESCRIPTION OF DESFONTAINE'S DRUM WEIRS.

By Prof. WILLIAM WATSON, late U. S. Commissioner.

In the spring of 1874, while at Paris, I made a number of excursions for the purpose of examining the admirable systems of river improvements which had attracted so much attention at the Vienna Exhibition. Having expressed a desire to see their practical working on a large scale to an eminent hydraulic engineer, I received from him a few days after a note, stating that one of his comrades, engineer of roads and bridges, stationed at Chateau Thierry, superintendent of a portion of the navigation of the Marne, intended to make a tour of inspection from Chateau Thierry to La Ferté.

I have spoken to him, said he, of your wish to visit the movable dams of the Seine and Marne, and he desires me to say that, if you will join him on Tuesday, he will be most happy to show you the works under his direction.

I accordingly left Paris in the evening, spent the night at Chateau Thierry, and early in the morning received a visit from M. J——, who proved to be one of my classmates at the School of Roads and Bridges in 1861; and to him I am indebted for the detailed explanations which enabled me to adequately appreciate this most remarkable system of inland navigation.

We embarked on a little steamboat, made entirely of steel, propelled by a small engine of five or six horse power, and soon arrived at the Azy dam. This dam has a fall of $2^{m}.10$, and may be thus described. It consists of:

1° A submersible lock, $7^{m}.80$ wide, 51^{m} long between the mitre sills, and placed on the bank used for towing.

2° Of a navigable pass, with Chanoine's system of falling gates. (To be described hereafter.)

3° A drum weir.

4° A pier, an abutment and other accessory works.

Each navigable pass has an opening of twenty-five meters. It is provided with twenty gates, like those of the upper Seine. Each gate has a width of $1^{m}.20$ and a height of 3^{m}.

The height of the upper bay above the sill is $3^{m}.31$.

The height of the lower bay above the sill $1^{m}.21$.

The sill of each pass, placed at first $0^{m}.60$ below low water, has been raised to $0^{m}.53$ by placing a cover $0^{m}.07$ thick upon the original sill, with a view of better protecting the gates when they are lowered. The space between two adjacent gates is $0^{m}.05$. When the gates are raised, their tops are $0^{m}.05$ below the normal level of the upper bay, thus permitting a slight overflow.

On the up-stream side of the twenty gates of each pass, are placed twenty fermettes $2^{m}.60$ in height, which can be raised or lowered into a recess in the floor or platform. These fermettes have a triple object, viz.:

1st. To support the lower story of a service bridge raised 2^{m} above low water, and upon which rolls a windlass to raise the gates.

2d. To receive a second story 1^{m} in height, so that the floor may be raised $0^{m}.50$ above the upper bay, and form a communication between the lock and the pier.

3d. To serve as a support for the needles of a Poiree dam. This consists of a screen of wooden battens called needles, $4^{m}.25$ long and $0^{m}.08$ square; the distance between their points of support is $3^{m}.70$; they form above the gates a second dam, and keep the water at its required height. In order not to strain unduly either the needles, or the gates, the force of the fall is equally divided between them.

The division of the fermettes into two parts, one placed above the other, is doubly advantageous; in the first place the fermettes are shorter, and, in consequence, the necessary interval between the last fermette and the pier is less, as

is also the recess to be made in the latter to receive the fermette; and finally, the first service bridge can be nearer the water surface, so that the gates' chains can be pulled under an angle more favorable for lifting them.

DESCRIPTION OF DESFONTAINE'S SYSTEM OF DRUM WEIRS IN THE MARNE BARRAGES.

Each weir forty-eight meters wide is composed of a fixed and movable portion.*

The fixed part consists of a mass of béton, faced with masonry, poured between two lines of sheet piles (Fig. 3), with an interval of $7^{m}.50$ between the lines. This mass rises to within $1^{m}.05$ of the upper bay level, or what is the same thing, to an average height of $1^{m}.20$ above low water. This fixed part is surmounted by 33 movable *hausses* or gates $1^{m}.50$ wide, with their tops, when they are up, at 1^{m} above the permanent portion; that is to say, at $0^{m}.05$ below the level of the upper bay. These gates were designed by M. Desfontaine, and called by him *hausses à tambour*, or drum gates.

The object of M. Desfontaine was to operate the dam by utilizing the power produced by the fall itself, so that the lockman should only have to direct this power in a simple and easy way. The solution is as complete as it is ingenious.

The moving apparatus (Fig. 3) consists of a series of gates, independent of each other, and turning around a horizontal hinge *a* placed in the middle. The upper half, *ab*, is the *hausse* or gate properly so-called; it is this which forms the upper bay. The lower half, *acd*, called the counter *hausse*, has no other function than to carry along the *hausse* in the movement impressed upon itself. It is inclosed in a quarter of a horizontal masonry cylinder of the same length, whose axis coincides with the hinge, and in which it can consequently make a quarter of a revolution. The limiting planes of this quarter of a cylinder, or drum, do not pass exactly through its axis. The horizontal one is slightly raised parallel to itself, and the vertical one has been similarly moved back, so as to leave the empty spaces *l* and *k* between the drum and the extreme positions of the counter *hausse*.

The counter *hausse* has also been slightly bent downward, in order to diminish the raising of the horizontal bounding surface, and thus prevent it from masking a part of the *hausse*.

Finally, the ends of the drum are closed by two sheet iron partitions in which two rectangular openings, *l* and *k*, have been made, corresponding to the empty spaces just mentioned. The successive drums with their *hausses* are made in the body of the weir. They rest upon the béton contained in the inclosures, and are in close contact with each other.

If we now consider the whole body of drums, we see that by their union below the crest of the weir, and along its whole length, they form a single tube, resting at one of its ends against the face of the pier, and at the other against the face of the abutment, and divided by the counter hausses into two longitudinal compartments.

In each pier, itself just above and below the line of the drums, two vertical wells, V and W, are made, communicating with the upper and lower bays respectively by the culverts E and D. These two wells also communicate with each other, by means of two pipes M and N, built into the masonry and closed at each end by valves *y* and *x*.

These pipes fork in front of the openings *l* and *k*, and passing through the pier, one connects with *l*, and the other with *k*. By the valves *x* and *y* on these two pipes the tube *l* may be put into communication with the upper bay, and *k* with the lower bay, or *vice versa*.

Let us suppose the *hausse* down, and *l* actually put in communication with the upper bay while at the same time *k* connects with the lower bay; the difference of pressure on the counter *hausse* will cause it to take the position *acd* carrying with it the *hausse ab*.

If, on the other hand, the tube *k* is put in communication with the upper bay, and *l* with the lower bay, the system is reversed, and the pressure forces the *hausse* to take the position *b'ac'd'*, that is it lowers the *hausse*.

* These dimensions are those of the Azy barrage which was personally examined. I am indebted for much valuable information concerning the Marne barrages to MM. Lagrené and Saint Yves; also to M. Jozon, Engineer *des Ponts et Chaussées*, stationed at Chateau Thierry, for a visit to these *barrages*, for the opportunities of seeing them in operation, as well as for numerous other courtesies.

DESFONTAINE'S DRUM-BARRAGE.

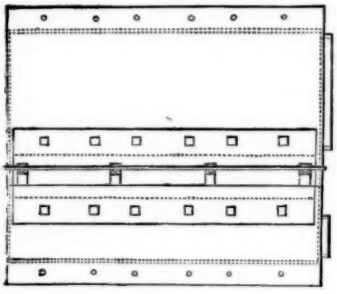


FIG. 1.—Plan of the *hausse* and its drum.

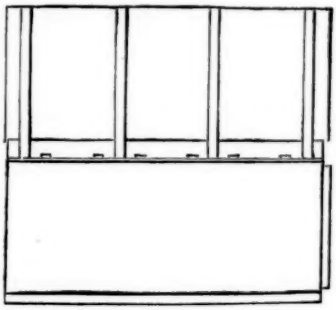
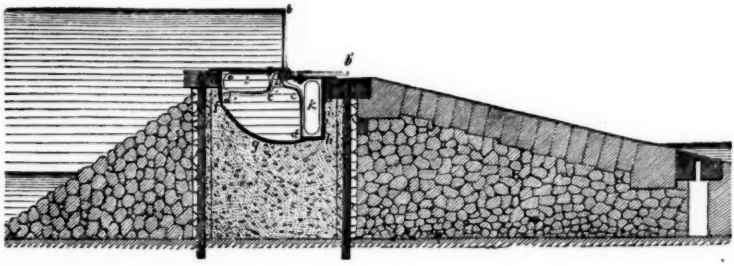


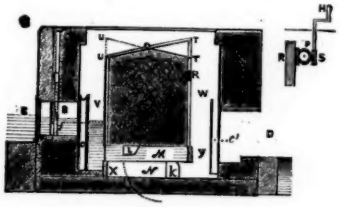
FIG. 2.—Elevation of the same.

FIG. 3.—Transverse Section of the Waste Weir.



EXPLANATION.—*a* is the axle; *a e f g* the drum; *a b* a hausse, or gate; *a c d* a counter-hausse; *b a c d* is the gate raised; *b' a' c' d'* is the gate lowered; *k* and *l* are transverse canals extending the whole width of the dam; *k* communicates with the lower and *l* with the upper bay, or *vice versa* according as the gate is to be raised or lowered. This communication is made by aqueducts and sluice-gates placed in the piers and abutments of the dam.

FIG. 4.—Transverse Section at a Pier.



EXPLANATION.—V and W are vertical wells in the pier, communicating by culverts E and D with the upper and lower bays, and with each other by the pipes M and N. M and N connect by forked branches with *l* and *k* respectively; the pipes M and N are closed by the valves *y* and *x*. These valves are attached to a balance beam T U and are moved up and down by a simple mechanism, viz., a crank H moving an endless screw S, S gearing into the pinion P, and P moving the rack R cut upon a small portion of the valve rod X U. B is an intercepting sluice. *c* and *c'* are coffer dams to be used in case of repairs.

The exact method by which these communications are made, is shown in Fig. 4.

M and N are the two pipes connecting virtually the upper and lower bays, the upper pipe M communicates with *l*, and the lower, N communicates with *k*; neither of these pipes is continuously open; they are closed by the valves *x* and *y*. When *x* is lowered and *y* raised, *l* communicates with the upper bay, and *k* with the lower bay, and *vice versa*. As these valves should move together and always have opposite positions, *i.e.*, when *x* is up *y* should be down, they are attached to a working beam T O U.

The motion of the beam is effected by means of a crank H, attached to an endless screw *s*, whose pinion *p*, works in a rack R cut upon the rod *x u*.

A very small amount of force exerted on the handle H, is sufficient to open the whole dam; M. Jozon put the handle into my hand, and after making a few revolutions with it I saw the gates begin to move, and in less than five minutes the whole dam 160 feet wide was opened, and the water roaring over its prostrate gates. By turning H in the contrary direction, one after another of the gates rose, as if by magic, against the force of the current, and in about three minutes all were up again, and quiet was entirely restored.

In conclusion, we may say in the words of M. Saint-Yves, that Desfontaine's system of movable drum weirs is certainly very ingenious and very satisfactory; it is reduced to a movement of valves, connected together by a balance beam, which work under a simple and easy impulse, and to gates in one piece which turn around a horizontal axle, without the complication of counterpoise, retaining chains, props or tallon bars.

The gates rise directly against the current, without the aid of detached or outside machinery. This remarkable result is obtained by the simplest means. The force utilized is not that of man increased by mechanical intermediaries, it is the very force to be overcome that assists the engineer, and blindly obeying the intelligent direction which is impressed upon it, contends against itself, and from the enemy it seems to be, becomes a docile instrument. In view of its unity, and of the simplicity of its conception and its working, it is one of the most remarkable inventions that ever originated from the laborious investigations of an engineer.

[*Historical Note.*—We extract the following from the notice which accompanied the model of Desfontaine's Drum Weir, exhibited in the French Department of Public Works: "In Holland from time immemorial fan-gates have been employed to close the irrigation canals. The unequal breadth of this kind of gate renders it susceptible to the power generated by a moderate lift. . . . Probably the idea passed from Holland to America, for about the year 1818 it was applied on the Lehigh river to gates with horizontal axes; it was described by M. Michel Chevalier in 1843, and advocated by M. Mary; the result of which was its trial in France on the Marne by MM. Desfontaine and Fleur-Saint-Denis. Although the work could not have been in more skillful hands, the first expectations were not realized. But this attempt failed not to leave in the inventive mind of M. Desfontaine the germ of an idea which carefully considered and diligently elaborated, has produced the present system; and it is with some pride that we return to the other side of the Atlantic the American barrage perfected under French auspices."]

The *Journal Officiel* states that the steam engines in France now give an aggregate of 1,500,000 indicated horse-power, representing a force of 4,500,000 horses, or 31,000,000 men—that is to say, ten times the true industrial population; the industrial population of France now amounts to 8,400,000 inhabitants, women, children, and old people included, among whom can be reckoned only 3,200,000 active workers. The first engine which appeared in France came from Boulton & Watt's works, at Birmingham, in 1789, and was used for distributing water in the city of Paris. It was not till 1824 that large works for construction of steam engines were begun. Some idea of the great comparative progress of the last 13 years may be had from the fact that in 1852 there were 6,000 fixed steam engines representing 45,000 H.P.; in 1863, 22,500, representing 618,000 H.P.

ON THE STRENGTH OF COLUMNS.

By E. HATZEL, Royal Architect, Bavaria.

Translated from the German by THOS. H. JOHNSON, C. E.

When a prismatic body is pressed together in the direction of its length, the complete resistance is only called in play when the pressure is uniformly distributed over the cross-section. Such a uniform distribution of the pressure occurs only when the length does not much exceed the least dimension of the cross-section.

On the other hand, when a prismatic body, whose length greatly exceeds its least transverse dimension, is compressed by a force acting parallel to its length, this force at the same time produces a lateral bending, and hence the body must resist compression and flexure at the same time, and is bent out on one side of the prism.

Prismatic bodies subjected to such compressive forces, may be classified as follows:

I. A short prism, whose length does not much exceed its least transverse dimension, and which is called upon to resist a uniform compression only.

II. A prism of greater proportionate length, which is called upon to resist flexure also; but in which the whole cross-section is exposed to pressure only.

III. A prism of so great length-ratio, that the flexure produces a strain of *tension* in a portion of the cross-section.

The resistance of a prismatic body depends chiefly on the strength of the material and area of the cross-section; but also on the ratio of length to least transverse dimension, and on the form of the cross-section; all of which factors must be included in any correct formula for the strength of such body.

In establishing such a formula we should consider also the kind and condition of the supporting body, and in what manner the load is distributed over its upper surface; in which connection it should be observed, that for a load unequally distributed over the upper end surface, the resistance to compression and flexure must be made greater than for an uniformly distributed load. It is, however, generally assumed that the supporting column is vertical, that the load is uniformly distributed over the upper surface, and that the compressive force acts vertically downwards.

§ 1. When a short prism standing erect, is loaded with a uniform load, the pressure is uniformly distributed over the whole area of each cross-section. In consequence of this uniform compression, the material of the prism undergoes a shortening of its height, and an enlargement of its section, in a horizontal direction. In this resultant change of form, the shortening of the material in its height is uniform throughout the mass; but the horizontal enlargement is dependent on the form of the cross-section. Thus in a cylinder under a uniform compression, the enlargement is distributed from the center of the circular section outwards, through uniformly concentric circles, and results in an uniform enlargement in the direction of all the radii. In all other forms of cross section in which the diameters through the centers of gravity of the section are unequal, it is found that the increments in the lengths of the several diameters are inversely proportional to lengths of the diameters themselves.

The resulting change of form may be readily observed, when we assume a strong pressure, and a short cylinder or prism of some material which is very elastic, and receives a considerable change of form from the pressure.

In this change of form the upper and lower end surfaces sustain but very slight enlargement, because they are prevented from spreading by reason of the friction existing there. This enlargement increases from the ends towards the middle of the height in such ratio as to produce a curved profile, and the original outline of the cylinder is changed to the form $h,A,giBk$, (Fig. 1).

In one and the same cross-section of a cylinder, the enlargement is wholly uniform, and is of equal size in the direction of all radii, forming the new outline A′C′B′D′, which is similar to the original section and concentric with it.

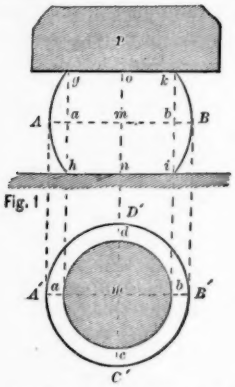


Fig. 1

The resistance of a short cylinder to a uniform force is proportional to the cross-sectional area, and we have

$$P = KA \quad . \quad . \quad . \quad . \quad (1)$$

in which P = the compressive force

K = the resistance per sq. unit of section

A = the area of the cross-section.

§ 2. The resistance which the square cross-section *efgh* (Fig. 2), offers to ex-

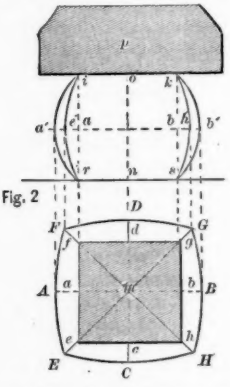


Fig. 2

pansion along the different transverse lines *amb*, *cmd*, *emg* and *fmh*, is proportional to the lengths of those lines; and in the resulting enlargement, the shorter line *amb* sustains the greatest extension, $a\mathrm{A} + b\mathrm{B}$; and the diagonals *emg* and *fmh* sustain the least enlargement. In consequence of this the enlarged cross-section takes the form of a quadrilateral bounded by curved sides, convex outward.

Because of the unequal increments, the several cross-sections are made to differ, just as the lines of one and the same cross-section become different; so that each of the four sides becomes a warped surface.

When a square cross-section becomes extended to the limit of resistance of its shortest transverse line, a separation of its parts occurs on these lines, before the resistance in the direction of the diagonals has been exhausted, and hence the compression resistance of the whole cross-section is not made available. Therefore, the compression resistance K, of the unit surface of the square cross-section, will not be exactly the same as for a circular section.

Let this breaking resistance $\mathrm{K}_0 = \frac{1}{n}\mathrm{K}_2$; denote the moment of resistance of the prism by P_1, and the side of the square by a. We then have

$$\mathrm{P}_1 = \mathrm{K}_0\mathrm{A} = \left(\frac{1}{n}\mathrm{K}_2\right)a^2 \quad . \quad . \quad (2)$$

When the cylinder and prism have equal cross-sectional areas, their respective resistances are limited to that which their cross-sections oppose to enlargement and separation in the direction of their least transverse diameters, and which is proportional to the lengths of those lines. But when a circle and square have equal areas, the least transverse diameter = the side = $a = 0.8864\ d$.

Substituting this in eq. (2) we have for a *square* prism

$$\mathrm{P}_1 = 0.8864\ \mathrm{KA} = \frac{\mathrm{KA}}{1.12} \quad . \quad (3)$$

LONG COLUMNS.

When a prismatic body, whose length is considerably greater than its least transverse dimension, is compressed by a force parallel to its length, then that force causes at the same time a shortening of its length, and a lateral bending of the prism, and calls into play the resistance of the material both to compression and to bending.

When a prismatic body whose longitudinal axis AB, (Fig. 4) is originally vertical and fastened at its base B, is subjected to a vertical force, P, at its upper end A, it becomes bent to the line BFA. The amount of bending is, however, so little that the length of the curved line

AB, may be considered equal to its abscissa AC.

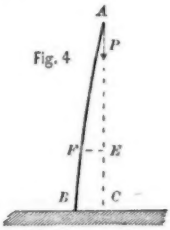


Fig. 4

Let l_1=AC=AB=the length of the bent line.

f=CB=the ordinate of the lower end B.

x=AE and Vy=EF=the ordinates of a point F.

δ=radius of curvature at the point F.

A=cross-sectional area of the prismatic body.

d=diameter of its circular, or least side of its rectangular cross-section.

I^d=moment of inertia of the cross-section, when its whole surface is exposed to compression.

I=moment of inertia of the cross-section when a part of its surface is in tension.

E=modulus of elasticity of the material.

$\lambda=\frac{K}{E}$=greatest possible shortening which the material can sustain per unit of length.

The force P, acting vertically downward, exerts on each cross-section a compression which is equal to P, and has the same value for all cross-sections, and at the same time each cross-section is subjected to a bending force, of which the moment in reference to any chosen point F is Py, and which calls into play the bending elasticity of the cross-section.

For the condition of equilibrium between the force P, and the compression and flexure produced by it, we have the following limiting equations. With reference to the uniform pressure on the cross-section it is

$$P=KA \quad . \quad . \quad . \quad . \quad (a)$$

And with reference to the bending alone,

$$Py=\frac{KI_d}{d} \quad . \quad . \quad . \quad . \quad (b)$$

From (a) we have $K=\frac{P}{A}$ and from (b), $K=\frac{d}{I_d}Py$, multiplying each of these expressions by $\frac{1}{E}$ we have

$$\frac{K}{E}=\frac{P}{AE} \quad . \quad . \quad . \quad . \quad . \quad (c)$$

$$\frac{K}{E}=\frac{d}{I_d E}Py \quad . \quad . \quad . \quad (d)$$

Again, we have $\frac{K}{E}=\lambda$, the greatest admissible shortening per unit of length, and P and Py are the forces by which this shortening is produced. Now then, both forces act simultaneously, and the shortening resulting from both of them taken together cannot be greater than $\frac{K}{E}$ its limit, and the sum of these values as found in equations (c) and (d) must be supposed equal to $\frac{K}{E}$.

We have, therefore, $\frac{K}{E}=\frac{P}{AE}+\frac{d}{I_d E}Py$.

from which $$KA=P\left(1+\frac{dA}{I_d}y\right) \quad . \quad (4)$$

$$KA=P\left(1+\frac{dA}{I_d}f\right) \quad . \quad (5)$$

The latter formula applies to the lower end B of the curve when y becomes $=f$.

The ordinates y and f can be determined from the co-ordinate equation of the line. This equation for an elastic line AB, Fig. 5, in which the direction of the force passes through both end points A and B, and the greatest lateral deflection CD=f occurs at the middle of its heights is

$$x=\sqrt{E\,I_d}\ \text{sin.}^{-1}\frac{y}{f} \quad . \quad . \quad . \quad (6)$$

$$y=f\ \text{sin.}\left(x\sqrt{\frac{P}{E\,I_d}}\right) \quad . \quad (7)$$

For the middle, D, of the height, where $y=f$ and $x=\frac{1}{2}l$, we have

$$\frac{f}{f}=\text{sin.}\sqrt{\frac{P}{E\,I_d}}.$$

But $\frac{f}{f}=1$, and therefore also = sin. 1;

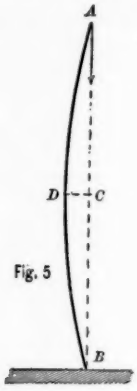


Fig. 5

and sin. $1 = \sin. \frac{1}{2}\pi$. So we may put instead of the foregoing equation

$$\sin. 1 = \sin. \left(\frac{l}{2}\sqrt{\frac{P}{E I_d}}\right)$$

or $$\frac{1}{2}\pi = \frac{1}{2} l\sqrt{\frac{P}{E I_d}}$$

from which $$P = \frac{\pi^2}{l^2} E I_d \quad . \quad . \quad . \quad (e)$$

The ordinate f has thus been eliminated, and the force P can be determined without knowing the bending distance f.

The radius of curvature for any point of the elastic line is

$$\delta = \frac{E I_d}{P y} \quad . \quad . \quad . \quad . \quad (f)$$

For the point D, in the middle of the height, when y becomes $= f$, it is

$$\delta = \frac{E I_d}{P f} = \frac{l^2}{\pi^2 f} \quad . \quad . \quad (g)$$

or $$\frac{E I_d}{P} = \frac{l^2}{\pi^2}$$

which may also be obtained by transposition of eq. (e).

A small part a, b, c, d, of a bent prism, Fig. 6, which in its unbent condition had

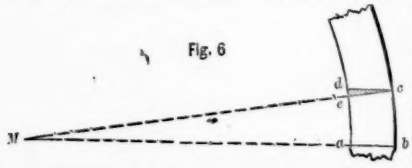


Fig. 6

the sections ab and cd parallel, and the length $ad = bc = 1$, in consequence of the bending is compressed together through the height ed, and is changed into the form c, e, a, b.

Let $\delta = c\,M$ = radius of curvature.

$\lambda = de$ = greatest admissible shortening which the material can sustain in the length $ad = 1$.

In the triangles $b\,M\,c$ and $d\,c\,e$, we have the proportion

$$b\,M : b\,c = c\,d : d\,e \quad \text{or} \quad \delta : 1 = d : \lambda$$

from which $\delta = \frac{d}{\lambda}$. Substituting this value for δ in eq. (g) we have

$$f = \frac{\lambda l^2}{\pi^2 d} \quad . \quad . \quad . \quad . \quad . \quad (h)$$

Substituting this value for f in eq. (5) we have

$$A = \frac{P}{K}\left(1 + \frac{\lambda l^2}{\pi^2}\frac{A}{I_d}\right) \quad . \quad . \quad (8)$$

$$P = \frac{K A}{1 + \frac{\lambda l^2}{\pi^2}\frac{A}{I_d}} = \frac{K A}{1 + 0.1013\,\lambda l^2 \frac{A}{I_d}} \quad (9)$$

When a prismatic body sustains a considerable bending and a part of the cross-section is in *tension*, then we obtain for its resistance P, the same expressions as in (8) and (9), except that in this case we must use, instead of I_d (the moment of inertia of the whole cross-section) the actual moment of inertia, I, of that part of the section which is in compression.

If, for instance, the bending of a prism, Fig. 7, is so large that one-half of the

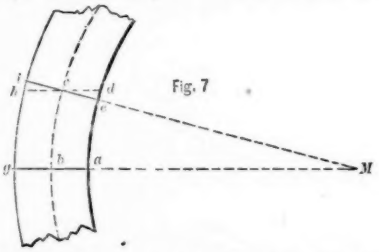


Fig. 7

cross-section, $h\,c\,i$, is in tension, and the neutral axis passes through the center c, then we have, in this case, $h\,c = c\,d = \frac{1}{2}d$, and we have then, instead of eqs. (b) and (d),

$$Py = \frac{K I}{\frac{1}{2}d} \text{ and } \frac{K}{E} = \frac{\frac{1}{2}d}{I A} Py.$$

Again, in the triangles $b\,M\,c$ and $d\,c\,e$ (Fig. 7) we have the proportion

$$\delta : 1 = \tfrac{1}{2} d : \lambda,$$

From which $$f = \frac{l^2 d}{\frac{1}{2} d \pi^2}$$

Substituting these values of $\frac{K}{E}$ and f in eqs. (5) and (9) we obtain

$$P = \frac{K A}{1 + \frac{\lambda l^2 A}{\pi^2 I}} \quad . \quad . \quad . \quad (10)$$

If a prismatic body is subjected to a considerable bending, a part of its cross-section may be in tension; but such strain of tension is only possible when the result of the bending force is greater than that of the uniform pressure; that is to say, when in eqs. (9) and (10) the expression $\frac{l^2 \lambda}{\pi^2} \cdot \frac{A}{I} > 1$.

For the force P_0 which produces tension in the cross-section, we have

$$P_0 = \frac{K A}{\frac{l^2 \lambda A}{\pi^2 I} - 1} \quad . \quad . \quad . \quad (11)$$

From which it follows:

1st. If in the foregoing equation the expression $\frac{l^2 \lambda A}{\pi^2 I}$ is *less* than 1, then P_0 has a *negative* value, and the cross-section is, at no place, in tension.

2d. If the expression $\frac{l^2 \lambda A}{\pi^2 I} = 1$, then is the tensile strain $P_0 = 0$. In this case the section is subjected to *compression only*, and the neutral axis passes through a point of the circumference; or is coincident with a side of the cross-section.

3d. If this expression is *greater* than 1, then some part of the cross-section is in tension; but that part sustaining compression is always greater than that part sustaining tension. The position of the neutral axis depends on the proportion in which the value of this expression is greater than 1, which in turn depends on the "length ratio" $\frac{l}{d}$, and the greatest shortening $\lambda = \frac{K}{E}$, which the material can "sustain per unit of length, and also on load per unit of surface."

4th. When the expression $\frac{l^2 \lambda A}{\pi^2 I}$ is very great in proportion to 1 then is that part of the cross-section subjected to *tension*, nearly as large as that part subjected to compression; and in proportion as the material offers equal resistance to both forces will the neutral axis more nearly approach the center of gravity of the section.

5th. A prism composed of horizontal layers, in which the pieces only rest upon each other, and are not united together, can only be loaded within the limit of $\frac{l^2 \lambda A}{\pi^2 I} < 1$. When such a prism is subjected to pressure beyond this limit, then there will be a part of the cross-section in tension, against which the joints of the cross-section can offer no resistance.

A prism A B (Fig. 4) with its lower end fastened to the floor is bent in the same proportion as the upper half A D (Fig. 5). Hence the formulae, established in the preceding sections for (Fig. 5), apply also to (Fig. 4) by making the length A B $= l_1$ (Fig. 4) equal to the half length A D $= \frac{l}{2}$ (Fig. 5); or $l = 2 l_1$. Substituting this value for l in eqs. (8) and (9) we obtain

$$F = \frac{P}{K}\left(1 + \frac{4 l_1^2 \lambda A}{\pi^2 I_d}\right) = \frac{P}{K}\left(1 + 0.4052 l_1^2 \lambda \frac{A}{I_d}\right) \quad (12)$$

$$P = \frac{K A}{1 + 0.4052 l_1^2 \lambda \frac{A}{I_d}}$$

For equal lengths, therefore, that part of the area which resists flexure must be four times as great for (Fig. 4) as for (Fig. 5).

Let $a b h g$ (Fig. 8) be a small portion of a bent prism, which is subjected to

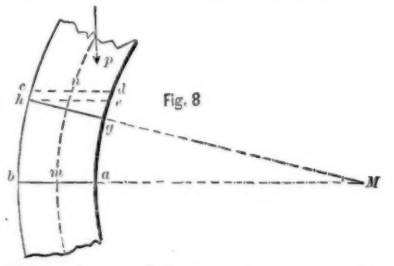


Fig. 8

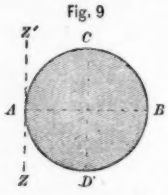
compression and flexure; but exposed to compression only, over its entire section, no part being in tension. This portion which in its original, unbent condition,

had parallel sections *ab* and *cd*, is shortened in height to the extent $ch=de$, by the uniform pressure P, and by the bending force, is compressed on one side to the extent *eg*.

The shortening *ehg*, thus caused by the bending moment, forms always a triangle; and the axis around which the unequal shortening occurs, always coincides with the outer edge *h* of the section; and hence for the condition that the entire cross-section shall be in compression, the *moment of inertia*, I_d, *of the section must be computed with reference to an axis tangential to the circumference, or coinciding with one side of the section.*

For the circular section A C B D (Fig. 9) the moment of inertia must be com-

Fig. 9



puted with reference to the axis Z A Z', tangential to the circumference at the point A, and its value is

$$I_d = \tfrac{1}{4}\left(\frac{d}{2}\right)^2 A + \left(\frac{d}{2}\right)^2 A$$

or $$I_d = \tfrac{5}{16} d^2 A \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Substituting this value in eq. (8) it becomes

$$A = \frac{P}{K}\left(1 + \frac{\lambda l^2}{\pi^2} \cdot \frac{A}{\frac{5}{16} d^2 A}\right)$$

or $$A = \frac{P}{K}\left(1 + \frac{16\,\lambda}{5\,\pi^2} \cdot \frac{l^2}{d^2}\right) \quad . \quad . \quad (14)$$

and by reduction

$$\left.\begin{aligned} A &= \frac{P}{K}\left\{1 + 0.3242\,\lambda\left(\frac{l}{d}\right)^2\right\} \\ P &= \frac{K\,A}{1 + 0.3242\,\lambda\left(\frac{l}{d}\right)^2} \end{aligned}\right\} \quad (15)$$

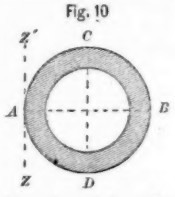
And for a cylinder in the condition of Fig. 4

$$\left.\begin{aligned} A &= \frac{P}{K}\left\{1 + 1.2968\,\lambda\left(\frac{l}{d}\right)^2\right\} \\ P &= \frac{K\,A}{1 + 1.2968\,\lambda\left(\frac{l}{d}\right)^2} \end{aligned}\right\} \quad (16)$$

From these equations we may compute the resistance of a cylinder of known sectional area, or the required sectional area for a known force P, if we know the modulus of resistance to compression K, and the modulus of elasticity E, for the material; and we may then determine at once the maximum length-ratio $\left\{\frac{l}{d}\right\}$ in which the cross-section is in compression only, and this gives the limit within which the formulae may be applied.

For the hollow cylinder (Fig. 10) the

Fig. 10



moment of inertia with reference to the axis Z Z' is

$$I_d = \tfrac{1}{4}\left(\frac{D}{2}\right)^2 A_0 + \left(\frac{D}{2}\right)^2 A_0 - \left\{\tfrac{1}{4}\left(\frac{d}{2}\right)^2 a + \left(\frac{D}{2}\right)^2 a\right\}$$

or $$I_d = \tfrac{5}{16} D^2 A_0 - [\tfrac{1}{16} d^2 + \tfrac{1}{4} D^2]\,a \quad (17)$$

in which D=diameter of outer circle, *d*=diameter of inner circle, and A_0 and *a* respectively the areas of the outer and inner circles.

If we take, for example $d=\frac{3}{4}D$, then the preceding equation becomes

$$I_d = 0.1521\,D^2 A_0$$

And the area A of the annular section is

$$A = A_0 - a = \tfrac{7}{16} A_0$$

Substituting these values of I_d and A in equation (9), we have

$$P = \frac{K\,A}{1 + 0.2913\,\lambda\left\{\frac{l}{D}\right\}^2} \quad . \quad . \quad (18)$$

In a prism of square section A B C D (Fig. 11) the moment of inertia with reference to the axis ZZ', coinciding with the side AB of the section, is

$$I_d = \tfrac{1}{3} h^2 A,$$

in which *h*=the side of the square.

Substituting this value in eq. (9) and at the same time modifying it from eq.

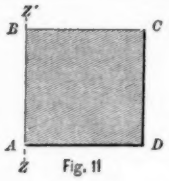


Fig. 11

(3) for the uniform compression on a square section, it becomes

$$P=\frac{K\,A}{1.12+0.3039\,\lambda\left\{\frac{l}{h}\right\}^2} \quad . \quad . \quad (19)$$

When a square and circle have equal areas the side of the square $a=0.8864d$; and substituting this value in the preceding equation we have

$$P=\frac{K\,A}{1.12+0.3857\lambda\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (20)$$

therefore, under otherwise equal conditions, the resistance of a cylinder column is greater than that of a square column of the same area, in the ratio of the divisions in the preceding equations, which is for compression as 0.886 : 1, and for flexure as 0.84 : 1.

APPLICATION OF RESULTS.

Wrought Iron.—To apply the foregoing formulae to columns of different materials, it is only necessary to know the values of K and E for the material, and from them the value of $\lambda=\frac{K}{E}$.

For wrought iron, as shown by experiment K=42,500 lbs., and E=28,200,000 lbs.; hence

$$\lambda=\frac{42,500}{28,200,000}=0.0015.$$

Substituting this value in eq. (15) we have the expression for the *breaking weight* of a wrought iron cylinder, in the condition of Fig. 5

$$P=\frac{K\,A}{1+0.000486\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (21)$$

In this eq. the expression $0.000486\left\{\frac{l}{d}\right\}^2=1$ when $l=45.4\,d$, and until the height reaches this limit the section will be in compression only.

From the foregoing equation we find that when $l=45.4\,d$ the breaking load for a wrought iron cylinder is

$$P=\tfrac{1}{2}\,K\,A,$$

and when $l=d$, $P=K\,A$. Hence the strength of a cylinder of length $l=45.4d$ is only one half that of a short cylinder of equal area; or the section of the first must be twice that of the second, to sustain an equal load.

For a wrought iron cylinder in the condition of (Fig. 4) the limit of length $l_1=\frac{1}{2}\,l=22.7\,d$ within which no part of the section will be in tension.

In practice only a portion K′ of the breaking load K per unit of surface is used, because the structure must not be loaded to breaking. In this case we have the shortening per unit of height $\lambda'=\frac{K'}{E}$ less than $\frac{K}{E}$, and for the corresponding load from eq. (15)

$$P'=\frac{K'A}{1+0.3242\,\frac{K'}{E}\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (22)$$

When the resistance of the material to flexure is taken at about the elastic limit, and $K'=\frac{2}{5}\,K$, we have

$$\lambda=\tfrac{2}{5}\,\frac{K}{E}=0.0006$$

In compression, ordinarily one-fifth the breaking load is the largest allowed on iron structures. Using these values, the safe load on a wrought iron cylinder becomes

$$P'=\frac{8500\,A}{1+0.0001945\left\{\frac{l}{d}\right\}^2} \quad . \quad (23)$$

In this eq. the expression $0.0001945\left\{\frac{l}{d}\right\}^2=1$ when $l=72\,d$, and within this limit the section is in compression only, and no part in tension.

If we use one-fifth the bending resistance as well as for the crushing resistance, $\lambda'=0.0003$ and the limit of length becomes $l=101.4\,d$, [or $l'=50.7\,d$ for the condition of Fig. 4] in which the section sustains compression only.

Cast Iron.—The resistance of cast iron to compression is K = 106000 lbs. per square inch, and its modulus of elasticity E=14133000. Therefore,

$$\lambda=\frac{106000}{14133000}=0.0075$$

and eq. (15) becomes

$$P=\frac{K\,A}{1+0.00243\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (24)$$

In this, the expression $0.00243\left\{\frac{l}{d}\right\}^2=1$ when $l=20.3\,d$ [or $l'=10.15\,d$] which is the limit of length without tension.

If we use, as before, one-fifth the resistance of the material in both respects, we have

$$P=\frac{21200\,A}{1+0.0004863\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (25)$$

in which

$$0.0004863\left\{\frac{l}{d}\right\}^2=1 \text{ when } l=45.45\,d.$$

The resistance of a hollow cylinder of cast iron is as determined in equation 17. Taking, for example, the inner diameter $d=\frac{3}{4}D$, and making $\lambda'=\frac{\frac{1}{5}K}{E}=0.00375$, equation 18 then becomes

$$P'=\frac{K'A}{1+0.00109\left\{\frac{l}{D}\right\}^2} \quad . \quad . \quad (26)$$

In this eq. $0.00109\left\{\frac{l}{D}\right\}^2=1$ when $l=30.28\,D$, within which limit the section is subjected to compression only, when the load P' is not more than one half the breaking load.

Wood.—For the resistance of a cylinder of wood substituted in eqs. (15) and (16) the proper value of λ, which is, for breaking,

$$\lambda=\frac{K}{E}=\frac{7000}{1413000}=0.005$$

and the resistance of a wooden cylinder, therefore, becomes

$$P'=\frac{KA}{1+0.00162\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (27)$$

in which $0.00162\left\{\frac{l}{d}\right\}^2=1$ when $l=25\,d$.

If we take $\lambda'=\frac{1}{8}\frac{K}{E}=0.001666$, and the compression resistance at $K'=\frac{1}{8}K$, the resistance then becomes

$$P'=\frac{850\,A}{1+0.00054\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (28)$$

in which $0.00054\left\{\frac{l}{d}\right\}^2=1$ when $l=43\,d$ (Fig. 5) or $l'=21.5\,d$ (Fig. 4).

When the elastic modulus is taken at $\frac{1}{6}$, and $\lambda=0.000833$, we find $l=60.8\,d$, or $l'=30.4\,d$, as the limits within which the section is in compression only.

When the length-ratio exceeds the designated limits, a portion of the section will be in tension, and the foregoing formulae are no longer applicable.

When a cylinder, in consequence of greater length-ratio and load, is subjected to so great a bending that a part of the section is in tension, then will the neutral axis assume some position ZOZ' (Fig. 12) intermediate between the point

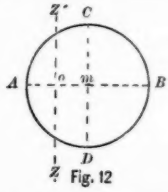


Fig. 12

A in the circumference, and the center point, *m*, of the section. When a cylinder of a material of nearly equal tensile and compressive resistance, as wrought iron or wood, has a length very great in proportion to its diameter, and owing to excessive load, is very much bent, then will that part of the section which is in tension be nearly as great as that part in compression, and the neutral axis will therefore fall nearly or on the central axis C *m* D, of the section. When the neutral axis falls in the central axis of the section, then is its moment of inertia

$$I=\tfrac{1}{16}\,d^2A.$$

Substituting this value in equation (10) we have for the cylinder in the condition of Fig. 5

$$P=\frac{KA}{1+1.62\,\lambda\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad . \quad (29)$$

from which we find the breaking load of a cylinder of wrought iron, for which $\lambda=0.0015$

$$P_1=\frac{KA}{1+0.00243\left\{\frac{l}{d}\right\}^2} \quad . \quad . \quad (30)$$

This formula applies only to such a cylinder as has a very great length-ratio,

and is so much bent, that the neutral axis falls in the central axis of the section. For a less important bending in which the neutral axis ZZ′ (Fig. 12) lies between the points m and A, we get a different value for P, the breaking load. Thus, for example, when the neutral axis lies in the middle between A and m, and the distance $Ao=o\,m=\frac{1}{2}r$, then for this special case, the moment of inertia $I=\frac{5}{16}d^2A$. Hence we have the expression,

$$\frac{\lambda l^2}{\pi^2}\cdot\frac{A}{I}=0.001215\left\{\frac{l}{d}\right\}^2$$

only half as great as in the above eq. (30), and making P_1 correspondingly greater.

Eqs. (21) and (30) give the limiting values of the resistance of a wrought iron cylinder. The strength of a cylinder whose length is equal to, or less than $45.4\,d$, is found from eq. (21), the neutral axis being tangential to the circumference; while eq. (30) applies only to the extreme case in which the neutral axis coincides with a diameter. For intermediate positions of the neutral axis, the resistance P_0 is greater than P_1 eq. (30), and less than P eq. (21). The real value of P_0 in this case cannot be accurately determined, so long as the position of the neutral axis is unknown.

The breaking load of a very long cylinder of wood, which sustains so great a bending that the neutral axis falls in the central axis of the section, is found from equation 29, by substituting the value of $\lambda=0.005$,

$$P=\frac{KA}{1+0.0081\left\{\frac{l}{d}\right\}^2}\quad\ldots\quad(31)$$

Ordinarily, the strength of a cylinder of wrought iron cr of wood, as used in construction, can be determined from eqs. (23) and (28), since, in practice, these numbers would not be allowed to sustain so great a bending as that a portion of the section would be in tension.

When a long prism of square section sustains so great a bending that the neutral axis falls in the central axis of the section, then there results in this case, under otherwise equal conditions, a greater resistance than in a cylinder.

A cast iron cylinder or prism should be allowed only so trifling a bending that the section would be in compression only, because of the comparatively feeble resistance of this material to tension.

A cast iron cylinder of great length should therefore only be loaded to such an extent that the resulting bending shall produce no tension in the cross-section.

Denote the compression resistance of the material by K, and the admissible portion of it by m; we then have from eq. (15)

$$P_n=\frac{m\,K\,A}{1+0.3242\frac{m\,K}{E}\left\{\frac{l}{d}\right\}^2}\quad.\quad(32)$$

The section will be subjected to compression only, and not to tension, when, in the foregoing equation,

$$0.3242\,\frac{m\,K}{E}\left\{\frac{l}{d}\right\}^2=1$$

putting for $\frac{K}{E}$ its value 0.0075 we have

$$m=411.5\left\{\frac{d}{l}\right\}^2$$

Substituting this value for m in the above equation, and observing that under the assumed conditions

$$1+0.3242\,\frac{m\,K}{E}\left\{\frac{l}{d}\right\}^2=2$$

we then have

$$P_n=205.75\left\{\frac{d}{l}\right\}^2 K\,A\quad.\quad.\quad(33)$$

making the safety modulus $K=\frac{1}{5}$ the crushing strength; viz. $\frac{1}{5}$ of 106,000 lbs. $=21200$ lbs., then

$$P=4{,}361{,}900\left\{\frac{d}{l}\right\}^2 A$$

Hence we have for cast iron cylinders of greater length-ratios than $l=20.d$, the following values for the allowed load P_n, in lbs. per square inch.

When	$l=20\,d$	then	$P_n=10910\,A$
"	$l=25\,d$	"	$P_n=6967\,A$
"	$l=30\,d$	"	$P_n=4848\,A$
"	$l=35\,d$	"	$P_n=3562\,A$
"	$l=40\,d$	"	$P_n=2728\,A$
"	$l=45\,d$	"	$P_n=2148\,A$
"	$l=50\,d$	"	$P_n=1738\,A$
"	$l=60\,d$	"	$P_n=1215\,A$
"	$l=70\,d$	"	$P_n=890\,A$
"	$l=80\,d$	"	$P_n=678\,A$
"	$l=90\,d$	"	$P_n=537\,A$
"	$l=100\,d$	"	$P_n=438\,A$

Hodgkinson found from numerous experiments on cast iron columns, the following mean values for the breaking load per square inch:

For $l = 30\,d$	P=24607 lbs.
For $l = 60\,d$	P= 7292 lbs.
For $l = 100\,d$	P= 3646 lbs.

For these length-ratios the foregoing computed values amount to:

$\frac{1}{6}$ the breaking load for $l = 30\,d$
$\frac{1}{6}$ the breaking load for $l = 60\,d$
$\frac{1}{8}$ the breaking load for $l = 100\,d$

The strength of a cast iron column, whose length is greater than $l=20\,d$, can therefore be determined with safety from the foregoing formulae.

STONE COLUMNS.

A free standing column or prism of stone or brick masonry cannot be fastened at its base as a standing support of wood or iron may be, but must hold its position chiefly through its weight and stability, because the cement used in the joints can only offer a slight resistance to tension.

But when a column A B (Fig. 4) which can be moved horizontally at its upper end A, sustains so little bending that no part of its section is in tension, then will the vertical compressive force produce the same effect in a column with the lower end not fastened as in a column fastened to the floor. Within this limit, therefore, the resistance of such a column can be computed from eq. (16).

The bending condition (Fig. 5) in which the direction of the force passes through both end-points, can only occur in a stone column which is so strongly constructed, and so firmly united to other parts, that it cannot yield laterally at its upper end. But ordinarily, only the smaller columns in the interior of a building are found so immovably fixed; while in a large, free standing column the upper end cannot well be so strongly united to other parts of the building. We can, therefore, for security, assume that in all stone or brick columns, the bending is of the class shown by Fig. 4, and hence we must compute the strength or dimensions from eq. (17).

For many varieties of stone the modulus (K) of resistance to crushing, is known from numerous experiments made with cube-shaped stones or short prisms. But this modulus (K) is not sufficient, in itself, to enable us to compute the bending resistance of a prism whose length is much greater than its least transverse dimension, because the modulus of elasticity (E) of the stone used, must also be known, but which hitherto has been determined for only a few kinds of stone. Besides, this modulus for the various kinds of stone shows such important variations, that no general value can be taken for it, as with iron and wood.

For one variety, namely, a white, hard sandstone, according to experiment, the modulus of resistance to crushing K= 5600 lbs., and the modulus of elasticity E=508800 lbs.

From these values we find $\lambda = 0.011$, and hence eq. (16) becomes for the breaking strength,

$$P = \frac{K\,A}{1 + 0.01426 \left\{ \frac{l_1}{d} \right\}^2} \quad . \quad . \quad (34)$$

In this, the expression $0.01426 \left\{ \frac{l_1}{d} \right\}^2 = 1$ when $l_1 = 8.38\,d$, within which limit the cross-section will be subjected to compression only.

In practice, stone is not allowed to be loaded beyond $\frac{1}{10}$ to $\frac{1}{15}$ of its breaking strength. Taking the factor of safety as to flexure at $\frac{1}{3}$, then $\lambda' = 0.00366$, and hence

$$P = \frac{K'A}{1 + 0.00475 \left\{ \frac{l_1}{d} \right\}^2}$$

whence $0.00475 \left\{ \frac{l_1}{d} \right\}^2 = 1$ when $l_1 = 14.51\,d$.

Taking the factor of safety as to flexure at $\frac{1}{6}$ then $\lambda = 0.00183$, and the limit of length becomes $l_1 = 20.51\,d$.

In practice, a stone column of greater length ratio than $l = 15\,d$ or $l = 20.5\,d$ is not used, and the latter ratio could not be used because it would not have the requisite stability. The resistance of a stone cylinder may, therefore, be computed from eq. (16).

BRICK COLUMNS.

I have made several experiments with brick pillars of various heights. These pillars had a square section of 4.7 inch on each side; and the bricks were united

with mortar joints 0.2 inch in thickness, composed of lime and sand with an admixture of cement.

From ten experiments with such pillars of various lengths, I obtained the following breaking loads:

When
$l = a$ ∴ K=710 to 735 lbs. per sq. in.
"$l = 6a$ ∴ K=517 to 455 " "
"$l = 9a$ ∴ K=435 to 452 " "
"$l = 13a$ ∴ K=346 " "

From one experiment with a brick pillar of 13.64 ft. height, and $12\frac{6}{8}$ in. $\times 6\frac{5}{16}$ in. section, in which the length-ratio was $l=26a$, the crushing resistance was found to be 95 lbs. per sq. in.

This pillar was bound together at its upper end, and there secured against displacement. The bending of the pillar must, therefore, follow the manner of Fig. 5, and the crushing and bending resistance of the column can be computed from eq. (10). Substituting in eq. (10) the value of the moment of inertia $I_d = \frac{1}{3} a^2 A$, which it has in a rectangular section in reference to one side, we then have

$$P = \frac{K A}{1 + 0.3039 \lambda \left\{\frac{l}{a}\right\}^2} \quad . \quad (36)$$

From the above cited experimental results, it appears that a pillar whose length is about $11\frac{1}{2}$ times its breadth, will be crushed by one-half the load that a pillar whose height $l=a$ would bear. Putting, now, $l = 11.6a$ as the limit at which $0.3039 \lambda \left\{\frac{l}{a}\right\}^2 = 1$, we then have $\lambda \times 0.3039 \ (11.6)^2 = 1$, whence $\lambda = 0.0244$.

Hence $$P = \frac{K A}{1 + 0.0074 \left\{\frac{l}{a}\right\}^2} \quad . \quad . \quad (37)$$

From which we find the breaking load of a brick pier of the following length-ratios, when the modulus of resistance K=700 lbs. per sq. in.:

When $l = 3a$ ∴ P=662 A
" $l = 6a$ ∴ P=558 A
" $l = 9a$ ∴ P=442 A
" $l = 12a$ ∴ P=342 A

The breaking load of a brick pier whose length l is greater than $12a$, can not be determined from the foregoing equation, since, in that case, a part of the section will be in tension, and therefore the moment of inertia will have a value different from that here taken.

But when a brick pier is loaded with only one-fifth the breaking weight, then

$$\frac{K'}{E} = \frac{\frac{1}{5} K}{E} = 0.00488$$

and eq. (36) then becomes

$$P = \frac{K A}{1 + 0.001483 \left\{\frac{l}{a}\right\}^2} \quad . \quad . \quad (38)$$

In which $0.001483 \left\{\frac{l}{a}\right\}^2 = 1$ when $l = 26a$ the limit of length, within which the section sustains compression only.

When the upper end is free to move laterally, then the eq. becomes

$$P = \frac{K A}{1 + 0.00593 \left\{\frac{l}{a}\right\}^2} \quad . \quad . \quad (39)$$

in which the limit is $l = 13a$.

Since a column or pillar of stone or brick masonry must sustain only so small a bending that the whole cross-section is in a state of compression, and no part in tension, we may compute the greatest allowable load in the same manner as was done for cast iron in eq. (33).

If m is the factor of safety, and K' the safe resistance to crushing, then from eq. (36), the greatest allowable load

$$P_n = \frac{m K' A}{1 + 0.3039 \frac{m K'}{E} \left\{\frac{l}{a}\right\}^2},$$

or since for brickwork $\frac{K}{E} = 0.0244$

$$P_n = \frac{m K' A}{1 + 0.0074 \, m \left\{\frac{l}{a}\right\}^2}$$

in which we will have compression only when

$$0.0074 \, m \left\{\frac{l}{a}\right\}^2 = 1$$

Hence $$m = 135 \left\{\frac{a}{l}\right\}^2$$

And since under the assumption made

$$1 + 0.0074 \, m \left\{\frac{l}{a}\right\}^2 = 2$$

then will

$$P_n = 67.5 \left\{\frac{a}{l}\right\}^2 K'A \quad . \quad (40)$$

If we make $K' = \frac{1}{10} K = 70$ lbs. per sq. in., then will

$$P_n = 4725 \left\{\frac{a}{l}\right\}^2 A.$$

From which we have computed the following table of greatest allowable load for brick piers whose length l is greater than $12a$:

When $l = 12a$ $\therefore$ $P_n = 33.07\,A$
" $l = 14a$ $\therefore$ $P_n = 24.31\,A$
" $l = 16a$ $\therefore$ $P_n = 18.61\,A$
" $l = 18a$ $\therefore$ $P_n = 14.70\,A$
" $l = 20a$ $\therefore$ $P_n = 11.91\,A$
" $l = 25a$ $\therefore$ $P_n = 7.63\,A$
" $l = 30a$ $\therefore$ $P_n = 5.30\,A$
" $l = 35a$ $\therefore$ $P_n = 3.89\,A$
" $l = 40a$ $\therefore$ $P_n = 2.96\,A$
" $l = 50a$ $\therefore$ $P_n = 1.91\,A$

When a brick pier is not confined at its upper end, but is free to move back and forth, then the greatest allowable load on such a pier, when l is greater than $6a$ is

$$P_n = 1192 \left\{\frac{a}{l}\right\}^2 A \quad . \quad . \quad (41)$$

from which we have obtained the following values:

When $l = 6a$ $\therefore$ $P_n = 0.475\,K'A = 33.25\,A$
" $l = 8a$ $\therefore$ $P_n = 0.254\,K'A = 17.78\,A$
" $l = 10a$ $\therefore$ $P_n = 0.168\,K'A = 11.76\,A$
" $l = 12a$ $\therefore$ $P_n = 0.117\,K'A = 8.19\,A$
" $l = 15a$ $\therefore$ $P_n = 0.075\,K'A = 5.25\,A$
" $l = 20a$ $\therefore$ $P_n = 0.042\,K'A = 2.94\,A$
" $l = 25a$ $\therefore$ $P_n = 0.027\,K'A = 1.89\,A$

The foregoing tables show that the resistance of a pier of masonry diminishes rapidly with the increase of height in proportion to thickness.

THE RELATIVE VALUE OF BLOWS AND PRESSURE.

From "The Engineer."

A most interesting treatise on the above subject has been recently published by Professor Kick, of the Prague Polytechnic, with diagrams of the results of some careful experiments. The whole is too long for us to transcribe *in extenso*, but we give such extracts, translated from the orignal German, as will introduce and illustrate, as nearly as possible in his own words, the Professor's theory and deductions. He mentions the numerous alterations of form in materials effected by a power acting either quietly and constantly, or by means of blows, calling special attention to the forging by means of hammers, in contrast with the Haswell press forge, to coining with the old stamp and fly press, instead of the Uhlhorn machine or hydraulic presses, to the fabrications of rod iron in the old forges, before the introduction of the modern rolling mills; and to the boring of stone with jumpers in contrast with the revolving diamond cutters of the present day. A glance at the above examples shows that the appliances, acting by means of blows, belong to an earlier age, and are undoubtedly more simple in construction than those whereby a quiet and suitably applied pressure executes the same, and ofttimes a better, work with advantage. It is not too much to say that the science of modern times is striving to replace the mechanical power exerted by blows by one acting by pressure. The foregoing illustrations show that a mechanical power, acting by blows, can be advantageously replaced by one acting by pressure, and that the labor expended in shaping materials under a quiet pressure is less than that wasted in using blows. The word pressure is here intended to comprise tension, deflection, crushing, breaking, pushing or torsion.

The work of shaping, be it stretching, shortening, bending, tearing, breaking, &c., amounts to bringing the smallest particles of any body, or a certain portion of them, into a different relative position. Every movement of the smallest particle, which by an alteration of form must alter its relative position, will

meet with a certain amount of latent resistance. Let us now suppose exactly the same alteration of form produced by a quiet pressure and by a blow, the latent resistances are overcome equally in both cases, therefore the amount of work done in each must also be equal, *i.e.*, the mechanical effect produced by the apparatus acting by pressure must be equal to the percussion effect or *vis viva* required of the tool acting by blows in producing the like result. This ideal demand cannot, however, be fulfilled, because the blow must always produce condensation of the direct impinging and impacted surfaces, and vibrations which have nothing to do with the actual intended alteration of form, hence considerable mechanical effect is wasted. If, for example, we allow a weight to fall on the center of a bar of iron supported at both ends, there will follow not only a certain deflection of the bar, but also a compression of the outside strata which come into immediate contact with the blow, and consequently an often very perceptible increase of heat. The mechanical equivalent for one unit of heat is well known to be 424 met. kilogrammes. There results then by a comparatively small increase of temperature a large loss of effort, and, in consequence of depression caused by the blow, also a considerable waste of percussive effect, intended for the alteration of form. To this must be added the almost unavoidable vibration of the supports. We admit that a blow fulfills an immense duty when a rigid substance has to be divided. One might say that the splitting of a block of stone in the usual way with wedges driven in with sledge hammers requires a very small amount of effort compared with what would be necessary to break the block by means of a load acting by pressure. This admits of explanation. By splitting a block with wedges only those particles which lie in the line of rupture require to be affected to obtain a separation of the same, while the whole block remains unaltered; whereas if a rupture be produced by weight acting by pressure, it will not be confined to the line required alone to be affected, but will be attended by expansions and contractions in every particle of the stone, of which the greater part would be useless, if not detrimental.

Redtenbacher's "Principles of Mechanics" says: "The advantage, therefore, of separating stone by wedges lies in this—that a certain *vis viva* acts only just on those portions which must be separated one from the other, whereas by crushing, the whole body is affected unnecessarily."

Professor Kick, without disputing this, says: "The same effect can also be produced without the application of blows, and instances the use, for the same purpose, of blocks of wood saturated with water, and freezing water, also the breaking of glass by first heating and then plunging it into cold water; and then asks, "If an equal result be not obtained with less expense of labor, and still without a blow?"

Quoting again from Redtenbacher:—"The driving of a pile into the earth without the use of blows is, so to say, a practical impossibility. If one were to try to press a pile into the ground in any way whatever, enormous preparations and precautions would be required—either one must place a weight on the pile which would nearly equal that of a house, or if one intended to effect the sinkage by a press, the press would require first of all to be made as fast to the ground as the pile itself would be when sunk; whence one must pre-suppose that that which is to be already exists." Kick answers: "Here too, for the sake of 'useful effect of blows,' the argument is carried a little too far." And proceeds: Without mentioning that screwing piles into the ground is both easy and advantageous, so much is certain, that the power of pressure necessary to sink them cannot be spoken of otherwise than exorbitant. Let us take the example of a house four stories high resting on a single row of piles 3ft. apart, centre to centre, with the usual thickness of walls, according to the Building Act of Bohemia, and we find that the loading of each pile equals about 25 tons. Certainly no one will maintain that a pressure of 25 tons is no longer to be obtained. If, for instance, a pile driving vessel or in driving land piles, a wagon be loaded with this weight, the necessary pressure can be brought into effect in either case. Even if a double or treble security be required, that is, that the piles shall not sink any further under a

weight of 50 or 100 tons, the application of such a weight is not accompanied by insurmountable difficulties.

In loose earth (sand) Captain Liernur, and later, others have obtained brilliant results by means of a thin pipe along the pile from whose orifice, in the neighborhood of the toe, a thin but powerful stream of water issues, which clears away and presses upwards the fine sand, and so facilitates the sinkage of the pile. Considered in this light, then, it appears very questionable if the use of blows in driving piles be attended with any advantage.

It certainly happens in the erection of works that a heavy body is moved, or in other words brought into position, by blows, and on account of its simplicity will always here and there be used. In this case, however, the mechanic must be quite aware that a certain amount of work which should be employed in moving, &c., is lost—*i.e.*, is converted into disintegration and heat, and that the lever windlasses are always more effective where they can be applied. As blows used in moving masses are attended by a waste of labor, on account of part of the efforts, accumulated in the substance inflicting the blow, being lost in disintegrating and heating, so when applied to alteration of form they always suffer a diminution of effect by compression of the outside strata, and the conversion of work into heat to a much greater extent than when a quiet and constant pressure is applied. It may be asserted that a fair comparison between the effect of blows and continuous pressure cannot be made, because the alteration of particles is quite different. In many cases this is true; nevertheless, in other and very numerous cases—*e.g.*, the bending of axles, coining, &c.—we may ask with good reason what the quantity of effect is for the same amount of deflection, stamping, &c., when blows are used as the power or when pressure. For such cases we have stated that, generally speaking, the expenditure of effort for the same effect is less with the application than that of blows. In support of the above assertions the following series of experiments, taken partly from publication, is given :—

(1) In a lecture on steel bronze, held on the 10th April, 1874, General Uchatius, the inventor of the new Austrian fieldpiece, published the results of his trials of the tensile of cast iron for cannons to blows and strains. The length of the rod was 75 millimetres; sectional area, 0.5 square centimetres; weight of monkey, 1.15 kilogs.

	Meters.		Met. kilos. effect.
The rods tore asunder with	0.72	Fall with 1 blow, producing	0.828
" "	0.63	" 2 "	1.430
" "	0.54	" 4 "	2.480
" "	0.45	" 8 "	4.140
" "	0.36	" 14 "	5.800
" "	0.27	" 37 "	11.490
" "	0.18	" 352 "	72.860
" "	0.09	" 2032 "	213.380

Consequently a breakage was effected with the least expenditure of effort, with a fall of 72 centimeter—namely, 0.828 met. kilogs. It can be taken for granted that a fall somewhere between 0.63 meter and 0.72 meter would have been sufficient, but as with a fall of 0.63 meter two blows were found necessary, the labor expended by each being 0.715 met. kilog., it may be more safely asserted that 0.828 met. kilog. is the minimum effect of a blow necessary to cause rupture. An alteration of form is therefore obtained by strokes or blows with so much less expenditure of effort as the number and strength of the blows applied are fewer and stronger.

Let us now inquire what amount of labor is necessary to tear asunder the same materials by means of a continuous pressure or strain. The trials gave as follows: (*See Table on following page.*)

The effective labor required for tearing asunder a rod of cast iron 1 square centimeter sectional area is about 0.2 met. kilog; and therefore that the effective labor required for tearing asunder a bar of cast iron ½ square centimeter sectional area is about 0.1 met. kilog. If we compare this with the effective labor required for tearing asunder by a blow, the result is in favor of pressure as 8 to 1. The work required for extension up to the limit of elasticity with an area of ½ square centimeter is about 0.003 met. kilog., or equal to a blow of a weight of 1.15 kilog. from a height of 3 millimeters, whereas Uchatius found that with a fall of 30 millimeters with this weight the limit of elasticity was not exceeded.

Since this experiment shows that one strong blow results in a better application of the *vis viva* than a number of

Weight in kilogrammes per square centimeter.	Extension in 0.00001 of length.		Weight in kilogrammes per square centimeter.	Extension in 0.00001 of length.	
	Elastic.	Permanent.		Elastic.	Permanent.
100	2	7	1300	84	14
200	10	0	1400	92	19
300	15	0	1500	101	24
400	22	0	1600	110	30
500	27	0	1700	120	35
600	33	0	1800	130	50
700	38	2	1900	142	65
800	47	4	2000	157	81
900	54	5	2100	—	—
1000	61	6	2200	—	—
1100	68	8	2300	—	—
1200	76	10	2420	rupture.	rupture.

weaker blows, and that an equal effect is obtained with a less expenditure of labor by means of a quietly working pressure than by the one blow, it follows generally that blows are attended by a greater waste of power than pressure in performing the same work; and that this is so, as far as regards cast iron, the above trials certainly go far to prove.

(2) Mr. Robert Lane Haswell, of Vienna, made two comparative trials to bend an axle by means of quiet continuous pressure, and then to straighten the same by blows. If the permanent deflection be not very great, the expenditure of labor necessary to straighten it can be looked upon as being the same as that required to bend it, because the same blow—W × H—which had previously caused a certain deflection was found able when properly applied to straighten a bent axle. In the press used the weight of lever and scale amounted to 241.25 kilogs., the short arm was 210 millimeters, the long arm 4845 millimeters; therefore the transmission was $\frac{4845}{210}$, or 23.07. The distance between the underlying blocks was 1.5 meter. A trial with a wrought iron axle of 132.75 millimeters diameter gave the following results:.

Weight applied to lever.	Deflection.		Remarks.
	Elastic.	Permanent.	
kilogrammes.	millimeters.	millimeters.	
250	2.70	0	The weight applied must be added to 241.25 kilos. and the sum multiplied by 23.07 to ascertain the pressure applied to the center of the axle.
300	3.10	0	
350	3.46	0	
400	4.10	0.46	
425	4.60	0.75	
450	5.10	1.30	
475	6.60	2.60	
625	—	17.00	
685	—	24.00	

The same axle was straightened under the blows of a monkey.

Blow	Height of stroke. Meters.	Deflection in millimeters.
1	0.600	12
2	0.600	5
3	0.332	3
4	0.335	—2

The weight of the monkey being 649.5 kilogs., the entire expenditure of labor in straightening the axle—really a slight deflection over and above took place in the opposite direction—amounted to 1212.6 met. kilogs. For the straightening alone of 12 millimeters, 389.7 met. kilogs. were required. The proportion of press work to that of blows is nearly as 1 : 7.

Since, however, as Uchatius also found, that with repeated and weaker blows the expenditure of effort was still greater, we may, in making a comparison of the

whole work, safely assert that the entire press work of 125 met. kilogs. is, in proportion to the entire work of blows, 1212.6 met. kilogs., nearly as 1 : 10. A second trial with a Bessemer steel axle of 129.5 millimeters diameter, under the same press, was permanently deflected to an extent of 12.5 millimeters as follows:

Weight placed on lever in kilogrammes.	Deflection.	
	Elastic.	Permanent.
	mm.	mm.
25	1.50	—
50	2.00	—
75	2.00	—
135	2.75	—
210	3.20	—
260	3.40	—
285	3.50	—
385	3.99	—
485	4.99	—
585	5.66	0.9
760	7.70	1.5
885	8.40	3.5
1105	9.30	9.3
1183½	15.00	12.5

To straighten the same axle by blows the following results were obtained:

Blows.	Height of fall. Meters.	Deflection. millimeters.
1	0.60	7.0
2	0.70	2.5
3	0.60	0

The effective labor here was $649.5 \times 1.9 = 1234$ kilogs. By the application of quiet pressure the deflection between 7 millimetres and 12½ millimetres required an expenditure of effort = 75 met. kilogs. —according to area w, x, y, z, while the first blow expended 389.7 met. kilogs. In this case, therefore, the pressure compared with the blows is as 1 : 5.

(3) Trial of Bessemer steel rails, undertaken by the Locomotive Superintendent of the States Railway of India, published in the German edition of "Engineering" —now Stummer's *Ingenieur*:—

Press trial.			Blow trial. Monkey: 10 cwt.; fall, 5 ft.	
Tons	Deflection in inches		Blow.	Perman'nt deflection.
	Total.	Perman'nt		inches.
6	0.13	—	1	1.25
7	0.15	—	2	1.25?
8	0.18	0.02	3	1.35
9	0.50	0.32	4	1.35?
10	0.90	0.70	5	1.31
11	1.55	1.31	6	1.31
12	2.36	2.10	7	Broke.

The distance between supports was in each case 3 ft., the work required for the permanent deflection of 1.31 in. under the press was about 480 foot-pounds, and the work of the first blow, which caused a deflection of 1.25 in., was 5000 foot-pounds, whence the proportion of pressure to blows is as 1 : 10. In a second trial the results were :—

Press trial.			Blow trial.	
Tons	Total deflection.	Perman'nt deflection.	Blow.	Deflection
	inches.			
6	0.13	—	1	1.19
7	0.16	0.01	2	2.31
8	0.23	0.07	3	4.63
9	0.63	0.45	4	Broke.
10	1.27	1.07	—	—
11	2.35	2.02	—	—

The distance between bearers, fall and weight of monkey, the same as before. If we compare the work of the first blow, which caused a deflection of 1.19., with that which was required of the press to cause the same deflection, we find the proportion of 5000 : 420. The amount 420 is taken from a diagram not shown here. The press work expended here is to that of the blows as 1 : 12. Other trials of rails Nos. 4, 5, and 10, gave similar results; also one of a chilled rail No. 20.

(4) We laid a lath of red deal of the cross sectional dimensions of 13.7 millimetres and 19 millimetres in its strongest position, on two bearers 0.60 metres apart. By means of a quiet pressure—determined by a diagram—with an expenditure of work of about 0.3 met. kilogs. it was broken. A monkey weighing 3.43 kilogs., with a fall of 0.10

metres, was allowed to fall on a similar lath without breaking it, the rupture occurring only when the fall was increased to 0.21 metres, representing a work of 0.72 met. kilog. Here the proportion of pressure to blow is as 1 : 2.4.

(5) A glass rod of six millimetres diameter was fixed at one end in a pair of lead cheeks, and a scale weighing 235 grammes hung on to the other end at a distance of 17 millimetres from the bearing :—

			Kilogrammes.		
The deflection	with a	load of	0.235	was 2	millimetres.
"	"	"	0.435	" 3	"
"	"	"	0.735	" 4	"
"	"	"	0.985	" 5	"
"	"	"	1.135	" it broke.	

It has been shown that 0.34 met. kilog. is the expenditure of work in effecting a rupture.

TRIAL UNDER BLOWS.

20 grammes with 10 centimetres. Fall on end of rod represented as work of 0.2 k. centimetres without rupture.
50 grammes with 10 centimetres. Fall on end of rod represented as work of 0.5 k. centimetres without rupture.
100 grammes with 10 centimetres. Fall on end of rod represented as work of 1.0 k. centimetres, broke.

We can therefore deduce from this trial that for the same amount of work —*i.e.*, rupture under blows—a greater expenditure of labor was necessary, the proportion of pressure to blows being as 1 : 2.

It has now been proved, first by No. 1 of the series of trials, that a certain alteration of form can be produced by means of a blow with the least waste of labor, when only one blow, provided it is strong enough, be given; also by the other trials, such as of cast iron, wrought iron, steel, wood, and glass, that quiet, continuous effort gives a more favorable result with regard to the expenditure of labor than any other form of applied power; therefore the assertion made at first, that the "expenditure of effort for the same effect is less by the use of pressure than by that of blows," may be taken as confirmed.

The question will naturally be asked how it happens that the proportion between the effect of pressure and blow varies between 1 : 2 and 1 : 12. These proportions must vary, more owing to the trials referred to than to the character of the materials, because they were not made under entirely similar conditions. The softer and more elastic the supports are on which the materials to be tested are laid, the less effective will be the blow, and the greater the waste of labor transmitted to the supports or lost in vibration. If the weight does not fall directly on the material to be tested, but on some intervening medium, as in trial 1, then the result is affected by this. The great differences even in the same material, such as wrought iron—as shown in trials Nos. 2 and 3—are therefore explained.

We have seen above that with timber and glass the difference between the amount of work for a certain effect by pressure and by blow is not very great; several trials made to show in what proportion the expenditure of work stands which is required to press or to drive (with blows) a nail into wood, showed in their results sometimes in favor of the hammer, and sometimes in that of the press.

From the foregoing Professor Kick draws the following conclusions :—(1) If we use blows for shaping or dividing substances a greater expenditure or waste of labor is necessary than if a quiet pressure be used instead. (2) If we know the mechanical work necessary to separate or break a substance under pressure, we can be quite certain that one blow which requires the same expenditure of mechanical effort *will not* cause the separation or rupture. (3) If the mechanical labor for the transitory alteration of the substance up to its limit of elasticity be known, that labor if applied through the medium of blows will not affect the substance up to its elastic limit.

As Professor Kick intends to continue his investigations and experiments with a view to publishing them, we hope at some not distant date to be able to give our readers the results in a fuller and more tabulated form than the present. The question is one of the deepest interest, more especially when applied to the working of the enormous masses of metal which are now employed in armor plates and big guns, and unless the arguments here put forward can be successfully refuted, the monstrous waste of labor under the method of steam hammers is a subject of serious consideration for manufacturers and calculation for political economists. If it can be proved that the calculations made by the authorities of the Indian States Railways

apply equally to the working of metal when hot as to the disintegration of the same when cold under the effect of pressure as against that of blows, viz., as 1 : 12 (and it has already been proved that in the manufacture of wheels, crank axles, axle boxes, &c., under pressure, an immense saving in heats, time, labor, and consequently expense, is effected), then it only depends on the supply of material and the demand of the market, for our manufacturers by adopting this system to turn out in one month the present product of a year, or in a decade the productions of a century.

ON THE RELATIONSHIP OF STRUCTURE, DENSITY, AND CHEMICAL COMPOSITION OF STEEL.

By Prof. JOHN W. LANGLEY.

Read at the Buffalo Meeting of the American Association for the Advancement of Science.

At the present day, much attention is being given to the importance of studying the connection between the chemical composition and physical properties of matter, meaning by physical properties such characteristics as crystalline form, color, hardness, specific gravity, etc. The following paper is offered as a slight contribution to this department of knowledge.

There are two methods of investigating this subject: first, to take bodies whose chemical nature is intimately known, and to commence an examination of their physical character; the second, to take material long known and studied from the mechanical side, and to investigate its chemical composition. The latter is the method here followed.

Steel, from its great industrial importance, is the best known of all alloys, and its behaviour under mechanical forces has been most extensively studied, both by individuals and governments; but, unfortunately, the elaborate tables of tensile strength, elasticity, etc. thus produced, have not been supplemented by correspondingly thorough chemical analyses, because it has only very recently been surmised that slight variations in the composition of steel affect its behaviour more radically than do all the processes of the rolling-mill or the machine-shop. Within the last eighteen months, the United States have appointed a commission to study in detail the connection between the strength, elasticity, etc., of steel and iron, and their chemical composition as shown by analysis. The research, which is the basis of this paper, was commenced before the organization of the U. S. Commission; but after the General Government decided to take up the subject and to explore it for the benefit of engineers, all that part of the original design was, of course, abandoned, and our attention has been chiefly directed to a study of the chemical and molecular structure of steel—a field which it is probable will not be entered upon by the government commission.

In such an undertaking, the number of facts to be acquired and of subjects to be pursued in detail is very great; they are thus far in a very incomplete state, and I am therefore able to furnish a record of a portion only of the work done—that which merely serves as a foundation for future research. In March, 1874, Messrs. Miller, Metcalf, and Parkin, steel manufacturers of Pittsburg, selected eight samples of steel which were believed to form a set of graded specimens, the order being based on the quantity of carbon which they were supposed to contain. They were numbered from one to eight. On analysis, the quantity of carbon was found to follow the order of the numbers, while the other elements present—silicon, phosphorus, and sulphur—did not do so. As the method by which these samples were selected has an important bearing on the subject in hand, it will not be out of place to describe it.

The steel is melted in black-lead crucibles capable of holding about eighty pounds; when thoroughly fluid it is poured into cast-iron moulds, and when

cold, the top of the ingot is broken off, exposing a freshly-fractured surface whose plane is approximately at right angles to the axis of the ingot. The appearance now presented is that of confused groups of crystals, all appearing to have started from the outside and to have met in the center; this general form is common to all ingots, of whatever composition, but to the trained eye, and only to one long and critically exercised, a minute but indescribable difference is perceived between varying samples of steel, and this difference is now known to be owing almost wholly to variation in the amount of combined carbon, as the following table will show. This consists of twelve samples selected by the eye alone in April, 1875, and the analyses were made from drillings taken direct from the ingot before it had been heated or hammered:

TABLE II.

Ingot Nos.	Iron by Difference	Carbon.	Difference of Carbon.	Silicon.	Phosphate	Sulphur.*
1	99.614	.302	..	.019	.047	.018
2	99.455	.490	.188	.034	.005	.016
3	99.363	.529	.039	.043	.047	.018
4	99.270	.649	.120	.039	.030	.012
5	99.119	.801	.152	.026	.035	.016
6	99.086	.841	.040	.039	.024	.010
7	99.044	.867	.026	.057	.014	.018
8	99.040	.871	.004	.053	.024	.012
9	98.900	.955	.084	.059	.070	.016
10	98.861	1.005	.050	.088	.034	.012
11	98.752	1.058	.053	.120	.064	.006
12	98.834	1.079	.021	.039	.044	.004
Mean			.071			

Here the carbon is seen to increase in quantity in the order of the numbers, while the other elements, with the exception of total iron, bear no relation to the numbers on the samples.

It has long been known that the structure of cast steel, as visible to the eye, bears some relation to the quantity of carbon present, and a rough classification by this method has been in practical use; but the above analysis show a very close connection between composition and structure, for differences of carbon so slight as seven-hundredths of one per cent. will impress such a change in the crystalline appearance of the metal that the eye of the expert can detect it, rarely ever making a mistake when the total carbon rises to a half per cent. or more. In mild steels the discrimination is less perfect.

The appearance of the fracture, by which the above twelve selections were made, can only be seen in the cold ingot before any operation, except the original one of casting, has been performed upon it. As soon as it is hammered, the structure changes in a most remarkable manner, so that all traces of the primitive condition *appears* to be lost; but although the crystalline form thus seems to be destroyed by heat or pressure, it can again be rendered evident by a special mode of treatment.

Another method of rendering visible to the eye the molecular and chemical changes which go on in steel, is by the process of hardening or tempering. When the metal is heated and plunged into water, it acquires, as every one knows, an increase of hardness, but also suffers a loss of ductility. If the heat to which the steel is raised just before plunging is too high, the metal acquires intense hardness, but it is so brittle as to be worthless; the fracture is of a bright, granular, or sandy character. In this state it is said to be *burned*, and it cannot again be restored to its former strength and ductility by annealing; it is ruined for all practical purposes, but it is in just this state that it again shows differences of structure corresponding with its content in carbon. The general nature of these changes induced by heat and tempering are sufficiently marked to be visible to an untrained eye, and can be illustrated by plunging a bar highly heated at one end and cold at the other, into water, and then breaking it off in pieces of equal length, when the fractures will be found to show appearances characteristic of the temperature to which the sample was raised.

The great molecular changes thus rendered evident are probably accompanied by changes of a chemical character between the iron and the carbon. According to Caron, such combinations do really occur, but the subject has thus far been too little investigated to warrant any decided expression of opinion.

There is a physical property which is

* The determinations of sulphur were made by Prof. A. R. Leeds, of Hoboken, N. J.

well known to be intimately connected with chemical structure, viz.: density, and in the case of union between gases it has risen to be sometimes even the criterion of combination. The specific gravity of steel and iron has been taken many thousand times before this, but not usually in conjuncton with analysis; it is believed that a study of the densities of a series of steels under varied conditions and as a sequel to analytic work, would develop facts of interest. Accordingly, samples were taken from the above twelve ingots by boring out a piece with a crown drill, breaking off the core left by the tool, and then grinding and polishing the surface smooth; also six bars drawn from the ingot were heated to *burning* at one end and were left cold at the other, then plunged into water, thus forming sets like the fractures just alluded to; each bar was then broken into six pieces and the ends rendered smooth so that the specific gravity could be taken.

In the following table the results are given: the upper horizontal line contains the numbers belonging to the ingots, the left hand vertical column gives the order of the pieces broken from the bars:

TABLE II.

Specific gravities of twelve samples of steel from the ingot; also of six hammered bars, each bar being overheated at one end and cold at the other, in this state plunged into water, and then broken into pieces of equal length.

	1	2	3	4	5	6	7	8	9	10	11	12
Ingot.....	7.855	7.836	7.841	7.829	7.838	7.824	7.819	7.818	7.813	7.087	7.803	7.805
BAR. Order of samples from bar:												
Burned 1.....	...	...	7.818	7.791	...	7.789	...	7.752	...	7.744	...	7.690
2.....	...	...	7.814	7.811	...	7.784	...	7.755	...	7.749	...	7.741
3.....	...	...	7.823	7.830	...	7.780	...	7.758	...	7.755	...	7.769
4.....	...	...	7.826	7.849	...	7.808	...	7.773	...	7.789	...	7.798
5.....	...	...	7.831	7.806	...	7.812	...	7.790	...	7.812	...	7.811
Cold 6.....	...	...	7.844	7.824	...	7.829	...	7.825	...	7.826	...	7.825

The temperature to which the densities are referred is 60° Fahr.

It is thus seen that the density decreases with the increase of carbon up to No. 5, which contains eight-tenths of one per cent. of carbon; below this number the influence of various physical conditions, such as rapidity of cooling, degree of fluididity before casting, etc., influence the specific gravity in an apparently erratic manner, though the numbers still continue to vary inversely as the carbon in a general sense; also if the influence of temperature on density is noted with regard to the sets of hardened samples, it will be seen that, taking the numbers from twelve to six (or those containing the highest amount of carbon), the specific gravity is lower the higher the temperature applied. Finally, the lowest horizontal line shows the densities of the metal as it left the hammer, and the upper horizontal ones belonging to the bars the expansion produced by over-heating. By the influence of hammering, all the pieces have been brought to nearly the same density, but as soon as the *burning* point is reached the steel is brought back nearly to the condition which it had at the moment of casting, and now the specific gravity is seen to vary in the same sense as the numbers in the ingot line above it.

A TYPE foundry in St. Paul has lately furnished the types for the *Framvavi*, an Iceland newspaper, to be published in the Icelandic colony at Keewatin, on the Red River, in British territory about sixty miles from Fort Garry. This will, according to the *New York World*, be the first newspaper published on the American Continent in the Icelandic language. The preparation of the types required the greatest care. They are in the Roman alphabet, but with a great many peculiarities in regard to accentuation, and are of a very antiquated form.

LIGHTING BY ELECTRICITY.*

From "Engineering."

BEYOND all question the use of electricity for purposes of illumination is destined in the immediate future to a very wide extension, both to replace in many instances the employment of gas, and in many others, and those of the highest importance, to supply a means of brilliant illumination, where at present only very feeble and imperfect sources of light are available. M. Fontaine, the author of this work, has devoted many years to the development and introduction of the gramme machine, so well known as a powerful means of producing the electric light, and largely employed for that and other purposes; and if we allow at once that he has shown a decided and possibly an undue preference for this machine, it has to be considered that his attention and interests have been concentrated upon it during many years. In this book he has contributed the most valuable addition to our practical knowledge of the subject, and although he, in a preface, gives a long list of other authors from whom he has derived much information, he is none the less deserving of much praise and thanks for the excellent manner in which he has performed his work. Naturally the first portion of the book is devoted to a consideration of the nature of the means of producing the electric light, as well as to a historical review of the various stages through which the science has passed from its inception to the present day. With regard to those subjects we need only say that M. Fontaine has written with much care and without tediousness, and we may pass on to the more practical portion of the book, as being of more interest and value to our readers.

The chapter on carbon points is very complete, and in considerable detail. The tabulated results given are of special value, as they are obtained from a number of careful experiments. We will refer particularly to one series of experiments. The points tried were: 1, of good retort coke; 2, those of M. Archereau; 3, those of M. Carré; and, 4, those of Gaudoin. The Archereau points are made of carbon finely divided and mixed with magnesia, the whole being brought into form under heavy pressure. The Carré points consist of

	Parts.
Very fine coke in almost impalpable powder	15
Calcined lamp-black	5
Liquid	7 to 8

The liquid is formed of thirty parts of sugar and twelve parts of gum. The whole is intimately mixed, and from one to three parts of water are added to make up for loss by evaporation. After being moulded under pressure the points are placed in a crucible and submitted to a high temperature. They are laid horizontally in the crucible, which is of cast iron, on a bed of coke dust, and each layer is separated by a sheet of paper. Between the upper layer and the cover a bed of coke dust, and then a bed of sand is placed. After the first operation, which should last from four to five hours, during which the points have to be maintained at a cherry heat, they are placed for two or three hours in a boiling and concentrated solution of cane sugar, being taken out two or three times to cool, in order to allow the solution to penetrate more freely. They are then drained and washed well in boiling water to dissolve the sugar on the surface.

After drying they are placed in a crucible and again heated, twice or more, until the desired density is attained, and finally they are cooled down slowly. These carbons are extremely tenacious, and can be freely used twenty inches in length and three-eighth inches in diameter without fear of breaking. The Gaudoin pencils are made of carbon produced from tar, resin, mineral oils, &c., and compressed in a mould. The following are the results obtained with the various forms by M. Fontaine during the present year:

* Eclairage à l'Electricité. Renseignements Pratiques. Par Hippolyte Fontaine. Paris: J. Baudry.

EXPERIMENTS MADE WITH VARIOUS CARBON POINTS, APRIL, 1877.

Nature of Carbon.	Form and Size.	Consumption per Hour.	Illuminating Power in Carcel Burner.	Length of Arc.	No. of Revolutions of Machine per Minute.	Regularity.
		in.		in.		
Retort, good quality	.354 in. square.	2.362	120	.094	820	Fair (1)
Archereau	.393 in. diameter	2.677	173	.118	820	None (2)
Carré	.354 in. diameter	2.716	175	.118	820	Medium (3)
Gaudoin type No. 1	.440 in. diameter	3.149	203	.118	820	Good (4)
Gaudoin compressed wood charcoal.	.452 in. diameter	3.070	240	.118	820	Very good(5)

1. Numerous scintillations. Projections. Carbons used very irregularly.
2. Very variable intensity of light. Wear of carbons in small facets.
3. Very variable intensity. Good wear of carbon.
4. Light somewhat red but very constant.
5. Light very white. Less fixed than with the Gaudoin carbon No. 6. Small variation.

In proportion to the light produced the wear of the points was for the

Gaudoin wood charcoal points	1.259	in. per	100 burners
Archereau	1.535	"	"
Carré	1.574	"	"
Gaudoin No. 1	1.574	"	"
Retort	1.968	"	"

Commenting upon the behaviour of these various carbons, M. Fontaine says: The light given by Gaudoin No. 1 was a little less regular than was obtained on a previous occasion; that given by the Carré varied in less than a minute from 100 to 250 burners; it turned around the points in the same way as with alternating currents. The Archereau pencils gave such a variable light that it was difficult to measure it by the photometer. The retort carbons alone preserved their durability, their luminous intensity, and unfortunately their irregularity.

Passing on to a historical review of electro-magnetic machines, M. Fontaine describes with much detail the latest form of the Gramme machine for producing a light equivalent to 2,000 burners. For lighting workshops and other industrial purposes, M. Gramme makes a machine with two magnets and one central ring. The weight of this latter is 396 lbs., its height 23.6 inches, its width 13.7 inches, and its length, including the driving pulley, 25.6 inches. The base weighs 264 lbs., and is 15.75 inches high. The copper wire of the electro-magnets weighs 61.5 lbs. and that of the ring 10.8 lbs. With this machine a light equal to 1,440 Carcel burners was produced, the speed being 900 revolutions per minute. The first workshop permanently illuminated by electricity was the Gramme atelier in 1873. The light was furnished by a single lamp, which took the place of twenty-five gas burners. During four years the work has been regular, and the cost has not exceeded 6d. per hour, including all charges. The space lighted is 40 feet square and 16 feet high. On a larger scale is the illumination of the Ducommun Works at Mulhouse. The main shop is 187 feet long and 92 feet wide. The lights are placed 17 feet above the ground, 69 feet apart longitudinally, and 46 feet transversely. The Gramme machines are placed in one of the boiler and engine houses. The total cost of establishment was £400, and the light obtained is equal to 400 burners. Many other workshops are also illuminated in the same way, among them we may mention those of MM. Sautter, Lemmonier & Co., of Paris, the Menier Chocolate Works at Grenel, Noiseul, and Roye, the spinning factories of Dieu-Obry, Daours (Somme) MM. Ricard fils, Mauressa (Barcelona), and MM. Buxeda, at Sabadell (Spain).

The lighting of the goods station at Chapelle-Paris, is also an important installation. It comprises a building 230 feet by 82 feet and 26 feet high, a shed

the same length, 49 feet wide, and 26 feet high, and a court-yard 65 feet wide separating the main station from the shed. The hall is lighted with two lamps about 14 feet above the ground, and the shed and yard with a single light. The cost of lighting is 7.5d. per hour and per lamp. The cost of establishment was £920.

An interesting application of the light has been made at Havre harbor extension works. The works at night were carried on by 150 laborers, over an area of about 300,000 square yards. The lamps here were placed at an elevation of about 50 feet, and each had a power of 500 burners. Minute objects were quite distinct at a distance from the lights of 350 feet, and the works were carried on with perfect ease.

In 1863 the first application of electric illumination was made to a lighthouse near Havre. The Alliance machine was employed, and since that date this method of lighting has been greatly extended in England, France, Russia, Austria, Sweden, and Egypt. Hitherto, however, the most powerful machine employed is equal only to 200 burners, but M. Fontaine states that the French Government is shortly going to experiment with a Gramme machine of 2000 burners. Of equal interest to light-house illumination is the application of the electric light on board ship, and enough has been done in this direction to encourage its wide extension. At the end of March, 1876, the America, of the General Transatlantic Company's line, was fitted with a Gramme machine, and all accessories. The reflectors are placed in the top of a tower made of plate iron, access being gained by an internal stairway. The height of the tower is sixteen feet four inches above the deck, the diameter is thirty-nine inches, and it is fixed in the forward part of the ship. The reflectors illuminate an arc of 225 degrees, leaving the ship almost entirely in the dark; the beam has a depth of about thirty-one inches. The Gramme machine employed has a power of 200 Carcel burners, and is driven by a three-cylinder Brotherhood engine with a speed of 850 revolutions per minute. The commutators controlling the action of the light are placed in the captain's cabin, and the light can be extinguished or produced at will without stopping the machine. The French Admiralty has recently established on board the Richelieu, and will shortly place on the Suffren, 500 burner Gramme machines, driven by a Brotherhood engine. This light it is expected will be of great service for torpedo defence. The light is concentrated in a cylindrical beam, which can be directed upon any desired point, the lamp and reflectors being mounted on a revolving frame, to which any desired inclination can also be given. M. Fontaine gives an interesting chapter on the power absorbed in producing the electric light, and refers at length to M. Tresca's valuable investigations of this subject.

The question of cost is considered, and this, though of secondary importance, when intensity of light is absolutely necessary, is one of the first points to be considered before attempting the application to industrial purposes. In this respect the author makes a most favorable comparison for the Gramme machine, which, while we do not endorse it, we consider of sufficient importance to summarise in this review. He bases his estimate on a machine, motor, apparatus, wires for transmission, &c., complete for 150 Carcel burners, and assumes four such apparatus are required to illuminate a given factory, 500 hours of lighting during the year being allowed for. The points cost 6d. per foot, and are consumed at the rate of 3½ inch per hour, including breakages. The following is the estimate:

	£
4 tons of coal at £1.4 per ton	5.6
523 feet of carbons	12.8
Maintenance of the four apparatus	10.
Amortization on capital, £400 at 10 per cent	40.
Total	68.4

For a single light the cost of maintenance is much higher in proportion, and this decreases rapidly as the number increases. The expense diminishes also with increased duration of use; thus at M. Menier's factory at Noiseul, where work is carried on throughout the night continuously, the cost is as follows:

	£
1046 feet of carbon	25.6
Annual maintenance	8.
Amortization	10.
	43.6

In this case, however, water power is used to drive the electro-magnetic machines; if steam were used 8 tons of coal would have to be added, which would bring the cost up to £54.4. With the latest type of Gramme machine it is claimed that these prices are considerably reduced. The following are stated as the proportional cost of various illuminating mediums as compared with the electric light:

Wax	75 to 1
Stearine	55 to 1
Colza oil	16 to 1
Gas	11 to 1

As the result of a detailed estimate for illuminating a factory with 415 gas lights and 6 electric lights, it is shown that the annual cost of the latter would be only 33 per cent. of the former, with six times the illuminating power.

The concluding chapters of this book are devoted to the consideration of lighting by incandescence, and on the divisibility of electric light as illustrated by the recent developments of M. Jablochkoff, which have recently been noticed in our columns. As we have already stated, M. Fontaine's book may be open to the objection of pressing too prominently forward the Gramme machine, but it is none the less a very valuable contribution to the literature of practical science, and treats very fully of a subject which is daily growing into increased importance.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS — TESTS OF AMERICAN IRON AND STEEL.— At a recent meeting of the Society, Prof. Robert H. Thurston was called upon to report the status of the "United States Board appointed to test Iron, Steel and other Metals." He gave an account of the origin of the movement to obtain the appointment of such a Board, and described the organization of that body, its plans and methods of work, its present position and its purposes for the future.

He remarked that the Board, having apparently reached very nearly the end of its history, it might be well to look to the beginning of the work. He proposed to follow closely the line of discussion pursued when making a similar statement, by request, before the Senate Committee on appropriations, March 6th, at which time he had been asked, as Secretary of the Board, to give an account of operations.

This plan of a systematic and thorough determination of the properties of the materials of construction made in the United States, and the scheme of making a really scientific examination of the composition and value of the metals used in their production, had an origin in two serious needs, and at a period which ante-dated the speaker's entrance into the Society. These two necessities arose from commercial conditions and from the requirements of constructing engineers.

We have been, for years, importing cast iron from abroad while we have domestic products of equal and even greater intrinsic value selling in our markets at lower price. We are importing boiler plate at 11 cents a pound when we can purchase American steel, vastly superior in all respects for the special purposes to which the former is applied, at 8 cents. We import vast quantities of foreign steel tools, when, at Pittsburgh and elsewhere, we make steel fully its equal. In New England and Pennsylvania, we have ores from which are made the finest cast-iron ordnance in the world. In Ohio, we make a metal for car-wheels such as never is seen in Europe, and of such tenacity and elasticity that foreign engineers listen incredulously when it is described. Our Lake Champlain ores make an iron equal to even Swedish for conversion into steel, and around Lake Superior and Missouri we have deposits from which come Bessemer metal vastly superior to the phosphorus-charged metal imported. New Jersey supplies us with zinc which meets with no competition as a pure metal and which can be used without purification for even chemical purposes; and our native copper is, as I know by experiment, absolutely free from admixture with injurious elements.

Yet, notwithstanding the fact that we possess the purest and best ores and make the best metals, we continue purchasing abroad.

This fact arises: *first*, from a natural conservatism which induces us to continue to pursue a course to which we have been accustomed even after we knew it to be an improper one; *second*, partly from that unfortunate American habit of self-depreciation which assumes, whatever comes from abroad to be, from that fact, superior to the product of our own country and of our own industry; and *third*, from the fact that our own people do not know and cannot readily be made to believe that our own materials are so excellent.

It was to meet the last difficulty, partly, that this Board was proposed. No private individual can afford to attempt the systematic and only truly economical methods of development of these facts, and no one has interest so general as to make it imperative that he should do so, were it in his power. Even were the work done, and well done, by a combination of private interests, it would still have comparatively little value, as the public invariably looks with distrust upon all statements made by private individuals, and suspects that private interests may have given tone to their reports. The maker of the very best iron, or of the best possible steel, cannot prove beyond cavil that his product is better than any similar metal purchased abroad. Only the General Government can institute an investigation that shall cover the whole field, that shall be systematic and scientifically thorough, and of which the reported results shall be accepted without distrust.

The second of the two classes of necessities leading to the creation of the Board was felt most keenly by our engineers and constructors, and by our manufacturers of machinery and of parts of structures. They knew comparatively little of the strength of our metals in small parts, and were still more seriously ignorant of the effect of making up any material in large sections and into the heavy members of bridges and other structures. They could not predicate dimensions on well ascertained measures of the strength of our iron, and were ignorant of the loads which could be sustained by heavy beams, girders, and columns made of this or of any other metals.

For years, they had been compelled to base their calculations on tables of strength of materials furnished by foreign experimenters, as Hodgkinson, Tredgold, Barlow, Morin, Rondelet, and Muschenbroeck, who gave the results of experiments on Carron iron and other metals, whose names were strange to American engineers, and which our builders never use. Recently, Kirkaldy, Styffe and some German experimenters have given us valuable information, but nothing of any considerable value has been published in reference to our domestic materials.

These facts, and many more which the speaker had not time to consider, led to the appointment by the Society, several years ago, of a committee to secure the inauguration of scientific and exhaustive examination of our American materials by a Government commission. This committee sent a delegation of its own members, and of other members of the Society, before the House Committee on Appropriations, in the spring of 1875, and secured the modification of a bill already in committee, which had originated with the Architect of the Treasury, and its adaptation to the plan proposed. Under the provisions of a bill thus secured from Congress, the President appointed a commission, consisting of two army and two navy officers and three experts from civil life; and this Board was organized and immediately adopted a very comprehensive plan of research, which was reported to the Society a year ago. Committees appointed to carry out the investigations proposed, issued circulars, which were published in all scientific and engineering periodicals, as well as in the Transactions of the Society, and which detailed these plans of work and asked advice and information. These circulars brought out very little useful material.

The Board contracted for a large testing machine, combining the plans of Messrs. Albert H. Emery and Charles E. Emery—the latter a Member of this Society—which machine was expected to have been long ago completed, but is not yet ready for work. It was intended to test large pieces, as heavy beams, girders, and columns.

While awaiting the completion of the machine, the Committees of the Board conducted their special investigations, where they could do so without the use of the large machine, making use of such other machines as were available.

Some of the Committee have reports, either completed or in progress. The committtee on Wrought Iron had finished several investigations of the methods of making iron, on the effect of impact on metal, on the effect of various strains, &c., &c. The Committee on Chain Cables has been studying the methods and material of cable manufacture. The committee on Tool Steel had completed a series of tests of the value of steels for cutting tools; analyzing them to determine their composition, and breaking them to ascertain their mechanical properties. The report is in preparation. The committee on Abrasion and Wear had completed that portion of its work formerly reported as in progress. The Committee on Metallic Alloys has determined the tenacity and other forms of resistance of all copper-tin alloys, their ductility, resilience, density, &c.; and the report is complete and in the hands of the copyist. A similar series of tests of copper-zinc alloys has been completed, and the report is in preparation; and an investigation of the properties of triple alloys of copper, tin, and zinc is in progress. The speaker described the methods of research adopted and indicated the general nature of results attained. The Committee on the Effects of Temperature has collected a large quantity of materials for test, and is still getting samples. The investigation is planned, but not yet commenced.

As just indicated, the Board has been working steadily for two years while awaiting the construction of its testing-machine—has done a large amount of work, and has completed, or has in preparation, some extended and probably valuable reports. The Board has been criticised because no reports have been yet made public. It should be remembered that where researches require months for their prosecution, the preparation of reports upon them usually requires an equal length of time, or sometimes greater. The speaker has sometimes acquired information in one day's work, which he had been unable to reduce to proper shape for publication in many days. Such criticism is evidently unjust, and never comes from those who have had experience in a kind of work in which the results of weeks of investigation are sometimes expressed in a single paragraph. Furthermore, the Board can only report to the President at the proper time, and the reports can only reach the country through the action of Congress. They can, therefore, not be presented piecemeal or at any desired date.

The speaker was permitted to state ascertained facts, but the Board had no authority to publish the reports in which only those facts could be found in their proper relations, except by presentation to the President, and publication under Act of Congress.

The speaker then described some methods of research adopted, and stated some interesting facts brought out by their application, including the reasons of variation of strength of iron and steel in bars of different sizes, the effect of strain after periods varying from one second to one year, the relation of composition, and of strength and ductility to the value of steel for tools, the methods which had enabled him to determine the mechanical proportion and value for constructive purposes of all possible

copper-tin, copper-zinc, and copper-tin-zinc alloys, the purposed methods of determining the effect of temperature, etc., etc.

The speaker stated that reports of progress had been made to the President, and that, a year ago, Congress had been requested to make an appropriation to enable the Board to continue its work, and to do some heavy work with its testing machine.

The appropriation was granted by the Senate, but defeated by the House Committee. The same experience had been met with during the session just closed. No opposition had been met with either in the Senate or on the floor of the House, and every well known member of either party, and especially those of recognized intelligence and standing, had taken real interest in the matter. The House Committee, with but one or two exceptions, had, however, determinedly refused, and had even inserted a provision in the Sundry Civil Bill of 1876–7, extinguishing the Board, when the money in hand should have been expended. That provision remains a law. The appropriation in hand will be expended during the coming year, 1877–8, and this Board, which has been procured and sustained by such earnest action, and so great an amount of hard work on the part of members of the Society, will be disbanded just as its plans and methods are thoroughly settled, and are bringing forth abundant fruit, and just as it is ready to undertake the most important of its researches —that on large parts of structures.

It is possible that earnest and determined action on the part of the Society, may preserve it, but it can only be done by taking steps as well as convince the members of the House Committee on Appropriations of the next Congress:

1st. That this work is of national importance in developing our mineral resources and manufacturing industries, and in securing safety of all large constructions; that it is an absolute necessity.

2d. That no individual can do such work, and that no combination of private individuals can make a complete and satisfactory investigation, even were the results of such work likely to be accepted as authoritative as would be the right of a Government Commission.

3d. That, while this work is as appropriately a matter of general legislation as the support of the Patent office, the Department of Agriculture, or of topographical and hydrographical surveys, it will secure returns of incalculable value, with insignificant expenditure.

If members of the House Committee can be shown these facts, the Board may possibly be continued; but it will only be by such convincing evidence as will fully controvert their pre-existing ideas, and convert them to a broader and more liberal faith. The Board has been formally endorsed by this Society, by the American Institute of Mining Engineers, the Iron and Steel Association, by all the technical schools, and by other institutions of learning, and has kept the members of the committees informed of the progress of its work. It has not been successful in securing proper recognition, notwithstanding all this, and notwithstanding the efforts of prominent men of both parties in Congress. It has done all that it, in propriety, can do, and will probably now simply present its reports on Committee work, state its readiness to go on with the greater work assigned it, and leave the matter to be decided as shall be determined by the House Committee on Appropriations, in the light of such evidence as they may thus be given. There is imminent danger that the Board will be discharged before it can report on the strength of a single 15 inch beam, or determine a single law relative to the resistances of parts of structures. It has, however, accepted its duties, and has undertaken them in good faith. Its members have discharged their duty faithfully, so far as they have been permitted, and have devoted, voluntarily, a vast amount of time to special research without compensation, and their only regret will arise from a natural reluctance to see their work interrupted, just when most certain to prove useful, and from the disappointment which, in common with all interested in the movement, they must feel at this premature interruption of a great and needed work.

They will find some slight compensation in the facts that they have, at least, organized a scheme which may, at some future time, be carried out by abler minds, that they have stimulated foreign nations to the consideration of the necessity of doing similar work, and thus, indirectly benefiting the world, and that they have been permitted to collect some valuable information in several important fields.

The speaker concluded by stating his belief that the importance of the subject and the evident and eager interest which had been taken in the matter by nearly all the members of the Society, would justify him in having so fully and freely stated the present status, and probable future of the Board appointed to test Iron, Steel and other Metals.

IRON AND STEEL NOTES.

Silicon Pig Iron.—At a recent meeting of the American Institute of Mining Engineers at Wilkes-Barre, Pa., Mr. Holley gave some account of the manufacture of silicon pig in France. This is a special pig, made as spiegel is in the blast furnace, containing as high as 10 per cent. silicon and some manganese. In using it a bath is made of spiegel, of ferromanganese, and rail ends, etc., are put in. When it gets to a state of fluidity that would in the ordinary process require the ferromanganese, the silicon pig is put in. The castings are free from blow holes. The ferromanganese in the bath serves a very important purpose—to keep out the oxygen. If oxygen is present it is taken up by it. The casting has almost the same physical properties as hammered steel. Another peculiarity is that it has a specific gravity higher than Whitworth's special steel—higher than hammered, and very much higher than ordinary steel. Another feature is that hammering does not seem to improve or injure it.—*Am. Manuf.*, xv, 7.

STEEL FOR SHIPBUILDING.—When H.M.'s ironclad Nelson was launched by Messrs. Jno. Elder and Co., on the Clyde, last November, Mr. Barnaby, the Chief Constructor of the English Navy, was present, and in the course of some remarks he said that that firm were building for the Admiralty six vessels constructed of a new material, viz., steel. The introduction of steel for armor had frequently been refeired to. They had made in England some experiments in this line with steel—an extremely "touchy" sort of material, something like flint glass, which would not break although it was thrown down six times, but perhaps if it were thrown down a seventh time it would fly all to pieces. The French had gone ahead of the English in this respect, and had produced an armor plate 12 ft. long, 4 ft. 6 in. wide, and 22 in. thick. That plate cost £2,000. It was put upon the side of a ship, a shot from a 100-ton gun struck it, and it went all to pieces. Steel might perhaps be used for armor some day, and he trusted Britain would not be behind other nations in introducing and using it in a proper manner; but at present he thought they must be very careful how they changed from well-made Sheffield iron plates to steel plates.—*Journal of Iron and Steel Institute*

RAILWAY NOTES.

STEEL RAILS IN THE UNITED STATES.—In the course of 1876 the Lake Shore and Michigan Southern Railroad Company laid 10,500 tons of steel rails upon its system. These rails, the whole cost of which was charged to revenue, covered 112 miles of line. There are now but 263 miles of iron rails in the track of the main line, and these remaining iron rails are to be replaced with steel rails as soon as possible. The use of steel rails appears to have had the effect of largely reducing the permanent way charges last year.

ROLLING STOCK ON LAKE SHORE AND MICHIGAN SOUTHERN.—At the close of 1876 the Lake Shore and Michigan Southern Railroad Company had nine more cars than at the commencement of the year. The aggregate car stock of the company was thus carried at the close of 1876 to 10,546 vehicles. The number of locomotives (495) owned by the company remained unaltered last year. The amount expended by the company last year in the maintenance of its rolling stock was 1,403,835 dols. The amount expended for new equipment in the six years ending with 1875 inclusive was 5,904,087 dols.; with this expenditure the company acquired 223 new locomotives and 4739 new cars.

RAILWAY EXPERIMENTS.—The Springfield (Mass.) *Republican* of recent date says:—A very interesting series of experiments have been in progress on the Boston and Albany road the past few days by means of the dynagraph-car of the Eastern Railway Association, in charge of P. H. Dudley, which has been run between Springfield and Worcester on both frieght and passenger trains to test the relative amount of power required at different points along the road, especial reference being had to the Springfield and Charlton grades. The experiment on the Modoc train, leaving Springfield at 6.30 a.m., which on the day in question consisted of two sleepers, four passenger and baggage-cars and the dynagraph-car, showed power required as follows:—For the first 2920ft. out of the depot the tension on the draw-bar was 6526 lb.; for the next mile 6460 lb., the rate of speed being 32 miles per hour; for the next 6200 lb., the speed being 36 miles, and for the last 1100ft. to the top of the grade 6250 lb. The last mile required the engine to produce 19,625,800 foot-pounds of power per minute. In going up the grade from East Brookfield to Charlton, beginning at the station, the tension on the draw-bar for the first 3880ft. was 5722lb.; for the first full mile, the velocity being 37.5 miles, 4280 lb.; for the second mile, with 37 miles velocity, 5232 lb.; third, with 36 miles velocity, 5450 lb.; fourth, which contains a sharp curve, with 37 miles velocity, 5612 lb.; fifth, with 41 miles velocity, 5230 lb.; and sixth, which ran a little past the summit at Charlton, 4356 lb. The engine had an 18in. by 24in. cylinder, and the track was in excellent condition. The maximum of the Springfield grade is 60ft. to the mile and the Charlton grade 51.47ft. At the sharpest curve the grade is about 49ft. Similar experiments were made on a freight-train of 27 cars drawn by the Adirondack, famous for her trials with the Mogul engine last summer, and showed that the tension on the draw-bar going up Springfield grade at a speed of 5.9 miles per hour was about 16,000 lb.; and the average strain going up Charlton grade at an average speed of about nine miles per hour was 14,500 lb., the power required in the first instance being 84,840,000 foot-pounds. Near the top of the grade the power of the engine was tested by applying the brakes, and it was found that running at four miles per hour, the engine could exert a tension of 17,000 lb. Beyond this point the drivers would slip and little progress was made. Really, the most important experiments in which the association is just now engaged are in testing the quality of iron and steel used for bridges, rails, axles and car wheels. Recent trials of the tenacity of iron used for various bridges and car axles indicate that much of the iron now in use will only stand about two-thirds the strain which it is guaranteed to resist. For instance, some iron now being put into a new bridge at the East, which is supposed to stand a pressure of 60, 000 lb. to the square inch, breaks readily at 40,000 lb., and a car axle supposed to be equal to 110,000 lb. snapped at 70,000 lb. When it is borne in mind that the calculations of bridge-building engineers are based on the guaranteed strength of the iron, the reason for the fall of iron bridges becomes apparent at once, and instead of wondering at an Ashtabula horror, the wonder rather is that it is not repeated. The Eastern Railroad Association, which is making these experiments, represents all the railroads on the Atlantic coast north of Richmond, Va., and east of Pittsburg and the Alleghanies and was organized about ten years ago, has for its object

the investigation of the validity of patents and claims to royalties for the use of the same. S. M. Whipple, of South Adams, is the general agent- The scope of the association has naturally broadened, and it has been for the past few years largely engaged in testing the merits of various railway equipments with the idea of getting the best in every department. The dynagraph-car is a curiosity in itself, containing, besides the dynagraph, which is an ingenious instrument registering exactly the amount of power required to pull a train, a chronograph which records the speed of the train every 7½ seconds, an anemometer which registers the velocity of the wind, whether natural or caused by the motion of the cars, and a complete set of instruments for testing the hardness, tenacity, ductility, density, and the amount of carbon in rails, axles, &c.

ENGINEERING STRUCTURES.

PROPOSED GREAT IRRIGATION WORKS FOR THE RHONE VALLEY.—FOR some years the breeding of the silkworm and the cultivation of the vine and of the madder-plant in the valley of the Rhone have suffered from various causes. The result has been a loss in the three branches of industry of about £3,200,000 yearly. It may be guessed what an amount of suffering such a reduction must be causing to thousands of families depending for their support upon them. M. Aristide Dumont, civil engineer, has proposed to cover this deficit by raising the cultivation of the soil and the breeding of cattle, as well as providing a remedy for restoring to health vines attacked by Phylloxera, by means of large irrigation works. His project, including the construction of an irrigation canal 310 miles long, is ably set forth in an article in the *Revue des Deux Mondes*, by M. F. Vidalin, of which we propose to give a short summary.

The importance of the project is evidenced by the facts that it has already been submitted to the Conseil des Ponts et Chaussees, that twenty-four local committees have been formed, instructed to collect data as to the consumption of water and its distribution, and that subscriptions have been received for the irrigation of 13,000 hectares (32,125 acres) of soil. It is pointed out that those most interested in the great undertaking are the railways, on account of the increased transport of agricultural produce; the landed proprietors, on account of the greater yield of forests, meadows, and vineyards; the different communes, by increasing the facilities for the supply of water; industry generally, by placing larger moving power at its disposal; trade and commerce, to both of which a new means of communication will be opened; and finally, the country as a whole, by larger receipts flowing into the public exchequer in the shape of increased tax-paying power.

The cost of construction of the principal canal and its feeders is estimated at £4,800,000., of which the State is to contribute £1,200,000., equal to a third of the outlay for constructing the principal canal. The remaining £3,600,000. are to be raised by subscription, to be paid back in ninety years, in annual instalments of £54,000, with interest at 4½ per cent.

The canal is to branch off from the Rhone below Vienne, near the rocks of Condrieu, and thence to follow the left bank of the river, with a fall of 0.24 meter per kilometer (15.26 in. per mile). The fall of the Rhone exceeding this ratio, a considerable difference in the two levels would soon be established. The canal is to extend above Valence and Montbeliard, to cross at the defile of Mornas in large syphons to the right shore, and to draw on its further course towards the most important towns of Southern France, Nimes, Lunel, Montpellier, Beziersi, and Narbonne. With a length of 310 miles, it would affect 220,000 hectares, or 543,650 acres, of soil to be irrigated, and offer a water supply to the 500,000 inhabitants of the above-named towns.

It is proposed to take from the Rhone 30 cubic meters (6,600 gallons) per second, and the same quantity from other rivers met with by the canal in its course. It is shown that the flow of water of the Rhone is 400 cubic meters (88,000 gallons) per second, that the Cavour Canal takes 110 cubic meters (24,210 gallons) from the river Po, and that the canal constructed at the foot of the Himalayas takes from the Ganges seven-eighths of its volume, or 44,000 gallons per second, in order to irrigate the so-called Doab for a length of 372 miles. The whole consumption of the Rhone Canal during the summer months, from April 15 to September 15, is estimated to be 930,000,000 cubic meters, and during the remainder of the year 700,000,000 cubic meters, corresponding to the proportions of the flow of the Rhone, which, as is well known, is mainly fed by the glaciers sending their waters down valley during the hot season of the year. During summer the meadows, during winter the vineyards, are to be irrigated. The yearly closing of the canals would have to take place in winter.

If for a surface representing a hectare 10,000 cubic meters of water are reckoned for irrigation, only 62,200 hectares could be watered in summer, and in case of more being required, the contents of the Rhone alone would have to be drawn upon, as it would not be advisable to withdraw more from its tributaries, on account of the works the power of which they supply. The requirement for a hectare of vineyard is estimated to be at least 6,000 cubic meters.

The rate of payment per 10,000 square meters to be irrigated is fixed at 63 francs, without regard to their mode of cultivation; in Upper Italy it is stated to be 75 francs. Irrigation would raise the yearly rent of a hectare of dry soil from 50 francs to from 150 to 200 francs. The power to be let out for industrial purposes for fifty years is estimated at 5,000 horse-power, a rent of 200 francs per year and power being expected. It is hoped that, in concequence of the great saving effected (a horse-power, if steam is applied, costing at least 500 francs), a large number of industrial undertakings will spring up between Vienne and Mornas, along the Paris-Marseilles line of railway. The new irrigation canal would offer to navigation between Condrieu and Mornas a way of transport, nearly 50 ft. wide and 10 ft. deep, which, with

little extra cost, might be made one of the most perfect waterways in existence, and which it might be desirable to continue as far as Marseilles and the Mediterranean. Its execution would ensure to sea-going ships of not more than 300 tons burthen the traffic between Havre, Paris, and Marseilles, compete with the St. Gothard Railway, and be to France a peaceable revenge for Sedan.

Of the great works to be undertaken in connection with the canal, the great syphon nearly two miles long, and to be constructed of sheet-iron, near Mornas, is especially mentioned. The inlet to the pipes is to be situate in a gigantic reservoir placed 230 ft. above the level of the valley ; the pipes are to cross the Rhone on a bridge, and the water conducted in them is to be emptied into a large basin on the other side. The cost of the syphon is estimated at £280,000.

ORDNANCE AND NAVAL.

IMPROVEMENTS IN CASTING SHELLS.—While guns and carriages have been developing, it is satisfactory to find that our projectiles are able to keep pace with them. This is by no means the matter-of-course thing that it might appear. The casting of a shell of 2,000 lbs. weight is not, of course, difficult because of its magnitude as a casting, for it is only a large one as compared with other shells. The difficulty lies in the peculiar requirements of the case. The chilling of a Palliser projectile of this size, for example, is clearly a more difficult matter than chilling a small one; but there are questions connected with shells of greater importance than this because of much wider application. The strains that fall on a shell when in the bore of a gun are so great as to call for a degree of excellence in the metal, and of soundness in the casting, such as has an interest for all those who have to do with foundries. When shells were made with a diameter less than that of the bore of the gun from which they were fired by about 0.08 inches, the gas generated on the explosion of the charge rushed past them, pressing the sides inwards to an extent that would scarcely be credited. We remember one shell of a nine inch gun that was measured very carefully after firing, which had its full diameter of 8.92 inches at the base, where it was completely supported, 8.90 at the head where the support was less direct, and only 8.55 near the middle; the shell having been thus pinched in towards a dumb-bell form to the extent of 0.37 inches, which in a cast iron hollow cylinder, as it is, with walls 1.5 inches thick, argues an amount of pressure that would hardly have been conceived was possible from the gas only escaping by windage, and acting only for the very short space of time during which the shell remains in the bore of the gun. Projectiles from our heaviest guns are now being fired with a copper gas check, which entirely reverses the state of things. For as there is now practically no windage and no escape of gas, the projectile experiences simply the strain of violent setting up which must come upon it, rather more suddenly and violently than when windage existed, other conditions being the same, We should expect a shell fired with a gas check to have its diameter slightly increased at the centre. We may also observe by the way that the soundness of the shell at the bottom is very severely tested both as to its absolute strength and the liability of the gas to force an entrance through any crevice that may exist, especially round the bush of the loading hole of a Palliser shell, which is, as many of our readers know, at the base. The question, however, that we want now to consider, as one of special interest to founders, is that of the actual strength of the iron shell. Until recently it was the practice to turn the external surface off the shells after they came from the foundry, by which any imperfections or scales in the surface were removed, and the shells by one very simple operation were brought to the required dimensions within the desired limits of manufacture. It has latterly, however, been discovered that a great sacrifice of strength was made by the removal of the outside skin of the casting, and means have been found to turn out the shell from the foundry in a condition that left all turning operations unnecessary. Indeed the perfection of the casting is such that no one would compare the turned shells with those that are now issued with their skin untouched after they leave the foundry.

We are now only speaking of what is open to the public. We should think it was probable that if application were made to the Superintendent of the Royal Laboratory, Colonel Fraser, he would be able to supply much information of special value to founders, for no one who saw the castings that are now being turned out in this department could fail to be very much struck by their perfection of form and the soundness of their surface. What is the extent of the gain in strength by the retention of the skin in place of its removal cannot be said, but by inference we should think it considerable. Now comes the question, by what means is this result achieved ? We always feel on delicate ground when speaking on questions of Government manufacture. We think, at all events, there can be no objection to pointing out what is open to any visitor who has eyes, ears, and a certain amount of knowledge. Our attention was called first to a change in the system of casting by a very simple thing. We happened to be asked to take a friend to visit the shell foundry, and we pointed out some metal in a ladle, speaking of its probable quality from the appearance of the break on its surface, when we became aware that the metal was not being poured as we expected into Palliser shell moulds but into those for common shell. Consequently it was clear that the breaking had not yet begun to take place rapidly, and we had been deceived as to its quality by the fact that it was being poured in a much hotter conditon than was formerly the case. We believe that this will be noticed to be the state of metal that is being cast throughout the foundry, and this may probably have much to say to the results that are being achieved. At all events the fact is plain that castings of extraordinary excellence are being turned out, and we should call the attention of iron-masters to the fact, with the

suggestion, that in all probability, if they considered it worth their while to apply to the Secretary of State for War, they might obtain information that might be very valuable, and we cannot suppose there would be any objection to supply such information on the part of the authorities.—*Engineer.*

BOOK NOTICES.

NEW CONSTRUCTIONS IN GRAPHICAL STATICS. By HENRY T. EDDY, C. E., Ph. D., Professor of Mathematics and Civil Engineering in the University of Cincinnati. Illustrated by ten engravings in the text and nine folding plates. New York: D. Van Nostrand. Price $1.50.

Readers of this Magazine do not need to be reminded of the value of this work, which is a reprint of the articles published in the Magazine from January to August. We quote the author's preface:

"At a meeting of the American Association for the Advancement of Science, held in August, 1876, at Buffalo, the writer read two papers, entitled respectively, 'A New Fundamental Method in Graphical Statics,' and, 'Certain New Constructions in Graphical Statics.' The latter paper furnishes the basis of the following pages.

"Most of the problems proposed have, it is thought, never been solved heretofore by graphical methods, though partial solutions have been obtained in certain cases.

"The possibility of obtaining a direct and complete solution of the various forms of the stiff arch rib is found to depend upon a theorem not hitherto recognized, as to the manner in which the equilibrium curve due to the applied weights is made to coincide as nearly as possible with the curve of the arch, which itself acts as a partial equilibrium curve. It is the difference in position of these two curves which is the measure of the bending moment in the arch. The solution of the arch is further simplified by showing that it depends upon that of a straight girder of the same cross section.

"The theorem above referred to, which may be properly named the 'Theorem Respecting the Coincidence of Closing Lines,' may be considered to occupy in relation to this subject, a place analogous to 'Gauss' Theorem of Least Constraint' in Dynamics, or 'Moseley's Theorem of Least Resistance' in Statics, and we may perhaps add to that of 'Legendre's Method of Least Squares,' in the Theory of Observations.

"Those who are acquainted with the intricate formulæ used in the analytic solution of this problem are aware that the actual relations are so covered up by these complications that from them a clear understanding of the manner in which the thrust, moment, and shear depend upon the applied weights is difficult, perhaps impossible. But it is hoped that the graphical investigation, which affords a pictorial representation, so to speak, of these quantities and their relations, may present no such difficulties. And further, the thrust, moment, and shear due to changes of temperature, or any cause which alters the span of the arch, are, it is believed, here for the first time obtained by a graphical process.

"A new general theorem is also enunciated, which affords the basis for a direct solution of the flexible arch rib, or suspension cable, and its stiffening truss.

"These discussions and constructions have led to a new investigation of the continuous girder in the most general case of variable moment of inertia. This investigation furnishes a complete graphical solution of the problem, and is accompanied by an analytic investigation in which the general formulæ appear for the first time in simple form.

"Another problem treated is that of the arch having block-work joints, such as are found in stone or brick arches, a case intermediate between the stiff and the flexible arch. A complete graphical solution of this problem was proposed by Poncelet, which the reader will find given by Woodbury in the case where the arch and load are symmetrical about the crown. The solution proposed is far simpler, susceptible of greater accuracy, and is not restricted by considerations of symmetry. Woodbury states that the solution given by him is correct for an unsymmetrical arch, but in this he is mistaken.

"The graphical construction for the stability of retaining walls is the first one proposed, so far as known, which employs the true thrust in its real direction, as shown by Rankine in his classic investigation of the thrust of homogeneous solids. It is in fact an adaptation of that most useful conception, 'Coulomb's Wedge of Maximum Pressure' to the results of Rankine's investigation.

"It has been found possible to obtain a complete solution of the dome by employing constructions analogous to those employed for the arch; and in particular it is believed that the dome of masonry is here investigated correctly for the first time, and the proper distinctions pointed out between it and the dome of metal.

"Finally, it may perhaps be said with truth, that neither of these problems can be solved with the same generality by analytic processes as by a graphical construction. The analysis almost always demands some kind of law or uniformity in the loading and in the structure sustaining the load, while the graphical method treats all cases without increase of complexity; and especially are the cases of discontinuity, either in the load or structure, difficult by analysis but easy by graphics."

The following is the table of contents: Introductory Formulæ and Theorems; Arch Rib with Fixed Ends; Arch Rib with Hinge Joint at the Crown; Temperature Strains; Arch Rib with End Joints; Arch Rib with Three Joints; Arch Rib with One End Joint; Arch Rib with Two Joints; Suspension Cable and Stiffening Truss; Continuous Girder with Variable Cross Section; Theorem of Three Moments; Flexible Arch Rib and Stiffening Truss; Arch of Masonry; Retaining Walls and Abutments; Spherical Dome of Metal; Spherical Dome of Masonry; Conical Domes of Metal and of Masonry.

NOUVELLE THEORIE DE LA POUSSEE DES TERRES. Par J. CURIE. Paris: Gauthier-Villars. For sale by D. Van Nostrand. Price $3.00.

Besides the Pressure of Earth, the author, almost of course, treats of the Stability of Retaining Walls. It is rare that so much space is devoted to this topic. It is an octavo volume of 285 pages, and is illustrated with thirty-seven elaborate cuts interspersed in the text, and six folding plates.

PHENOMENES PHYSIQUES DE LA PHONATION ET DE L'AUDITION. PAR J. GAVARRET. Paris: G. Masson. For sale by D. Van Nostrand. Price $4.00.

A new interest attaches to the subjects of sound and hearing, since the invention of the telephone.

The work before us which is a royal octavo volume of about 600 pages treats of the latest theories and especially of modes of experimenting employed by physicists. It covers about the same ground as Tyndall's lectures on sound. The illustrations are of excellent quality and number about one hundred.

BRITISH INDUSTRIES—HORTICULTURE. By F. W. BURRIDGE. London: Edward Stanford. For sale by D. Van Nostrand. Price $2.25.

This is the latest addition to this valuable series of technical works, but it is by no means the least important or least interesting to general readers. The author ably, but briefly, discusses the following topics: Commercial Gardening; Fruit Culture; Vegetable Culture; Culinary Vegetables; Salad Vegetables; Herbs; Decorative Plant Culture; Fruit and Vegetable Preserving; Plant Propagation; Hybridizing and Cross Breeding; Public Gardens; Gardening Industry Abroad; Collateral Industries of Gardening.

Several illustrations embellish the work.

A TREATISE ON ENGINEERING CONSTRUCTION: Embracing Discussions of the Principles Involved, and Descriptions of the Material Employed in Tunneling, Bridging, Canal and Road Building, etc., etc. By J. E. SHIELDS, C. E New York: D. Van Nostrand. Price $1.50.

Many and various subjects are treated in this little book, and all of them with exceeding brevity. It is a collection of rules, directions and formulas for the use of working engines, derived from the experiences of a thoroughly practical man, and are such as have been verified by frequent use.

The whole is presented under four general heads; viz, Foundations, Masonry, Tunnels and Engineering Geodesy.

In the first of these divisions are treated the characters of natural soils, and the various artificial constructions which serve as a base for engineering structures; among these latter are Planking, Concrete, Beton, Caissons, Piles, etc.

Under Masonry are presented the laws of Statical Equilibrium of Stone and Brick Arches, and Retaining Walls, together with the empirical rules sanctioned by long use.

"Tunnels" is made to include brief directions regarding Mortars and Cements; the character of stones both as regards strength and chemical composition. The construction of shafts and tunnels proper has, of course, a fair share of space; so also has quarrying and blasting, and the directions for selecting good timber.

Engineering Geodesy includes some brief rules for solutions of problems in what is called Higher Surveying in the text books; such as Finding the Latitude; Determining the Meridian; Leveling by the Barometer, etc.: also such miscellaneous rules and tables as could not properly be classified under either of the preceding heads.

Forty-two interspersed cuts illustrate the text.

REPORT OF CHIEF ENGINEER J. W. KING, UNITED STATES NAVY, ON EUROPEAN SHIPS OF WAR AND THEIR ARMAMENT, NAVAL ADMINISTRATION AND ECONOMY, MARINE CONSTRUCTIONS AND APPLIANCES, DOCKYARDS, &c. Washington: Government Printing Office.

The scope of this report is well explained by its title, and when we say that the promise of the title has been well fulfilled, it will be evident that Mr. King has produced a volume which, at the present time especially, possesses more than ordinary interest. It may appear somewhat curious to have to refer to a report to a foreign government to obtain information respecting our own naval force, but it is nevertheless a fact that no book published in this country contains so full an account of the vessels of our navy and their armament, &c., as is contained in Mr. King's report. We ourselves have from time to time published accounts of all new vessels added to our navy, and Mr. King has, as he acknowledges, availed himself of our pages, while he has also drawn information from other current publications and Government blue-books, but apart from the facts thus gleaned, he has collected a vast number of other particulars which have not, so far as we are aware, been published at all, while he has supplemented his descriptions by numerous sketches illustrating special points of arrangement and detail.

The whole report consists of 273 octavo pages, and of these 130 are devoted to descriptions of vessels in the British Navy, while about 80 pages more treat chiefly of our marine engines and boilers, our dockyards, and our naval administration, so that the navies of other European countries are dealt with briefly by comparison. Seeing that Mr. King evidently has the capacity for collecting information, the fair deduction to be drawn from his report is that the opportunities afforded abroad were not so great as he met with in this country, but he has nevertheless managed to collate a number of facts relating to foreign navies which just now possess much interest.

In the section of his report treating of marine engines Mr. King points out the overwhelming evidence in favor of the compound system, and says: "As yet, by no satisfactory device except compounding have great expansion and conse-

quent economy of fuel been obtained at sea. In the face of these facts, further discussion on the subject of adopting the compound engine for the vessels of our own navy is as useless as would be the discussion of the relative merits of the screw propeller and paddle wheel for ships of war." Mr. King also devotes a special section of his report to boilers, another to sea-valves and cocks, and steering gear, and others to torpedo boats, &c.

Altogether the report under notice contains much valuable and interesting information, and it forms a volume very creditable to its author.—*Engineering.*

MISCELLANEOUS.

DANUBIAN STEAM NAVIGATION COMPANY.—It appears that at the close of last year, this company possessed 196 steamers of aggregate force of 17,490 horse power. The company's revenue for 1876 amounted in round figures to 1,230,000*l.*; the profits realised for the year were about 140,000*l.*

M. A. BERTRAND has recently experimented upon electro-plating with aluminum, magnesium, cadmium, bismuth, antimony, and palladium. He had obtained deposits of aluminum on decomposing with a strong battery a solution of the double chloride of aluminium and ammonium. A plate of copper forming the negative pole, whitens gradually, and becomes covered with a layer of aluminum, which takes a brilliant polish under the burnisher. The double chloride of magnesium and ammonium in an aqueous solution is readily decomposed by the battery, giving in a few minutes strongly adherent and homogeneous deposits of magnesium upon a sheet of copper. It polishes readily. The battery must be powerful. Cadmium is best deposited from the bromide to which a little sulphuric acid has been added. It is then very coherent and very white, and takes a fine polish. The sulphate, if acidulated, also gives an immediate deposit of metallic cadmium, very adhesive, and capable of a fine polish. Bismuth is deposited from a solution of the double chloride of bismuth and ammonium upon copper or brass by the current from a Bunsen element. It is very adhesive; though mat, it is capable of taking a fine polish, and may be introduced in the decoration of objects of art. Antimony can be deposited from a solution of the double chloride of antimony and ammonium at common temperatures. It frequently serves to replace platinum-black in a number of fine art manufactures. Deposits of palladium are obtained with ease by means of the double chloride of palladium and ammonium, either with or without the battery. The solution must be perfectly neutral.

NOVEL METHOD OF DEEP SEA SOUNDING.—At a meeting of the Royal Society Dr. Siemens exhibited the instrument he has devised to ascertain the depth of the sea by a new means without using a sounding line. He has worked out the requirements, starting with the proposition that the total gravitation of the earth as measured on its normal surface is composed of the separate attractions of all its parts, and that the attractive influence of each equal volume varies directly as its density and inversely as the square of its distance from the point of measurement. The density of sea water being about 1.026 and that of the solid constituents composing the crust of the earth about 2.763 (this being the mean density of mountain limestone, granite basalt, slate and sandstone), it follows that an intervening depth of sea water must exercise a sensible influence upon total gravitation if measured on the surface of the sea. Dr. Siemens showed how this influence can be proved mathematically in considering, in the first place, the attractive value of any thin slice of subtance in a plane perpendicular to the earth's radius, supposing that the earth is regarded as a perfect sphere, of uniform density, and not affected by centrifugal force.

It was in 1859 that Dr. Siemens first attempted to construct an instrument based on these principles. The difficulties he then encountered he has since overcome, and the present instrument is the result of his latest work. He proposes to call it a bathometer, and it consists essentially of a vertical column of mercury contained in a steel tube having cup-like extensions at both extremities, so as to increase the terminal area of the mercury. The lower cup is closed by means of a corrugated diaphragm of thin steel plate, and the weight of the column of mercury is balanced in the centre of the diaphragm by the elastic force derived from two carefully-tempered spiral steel springs of the same length as the column of mercury. One of the peculiarities of this machanical arrangement is that it is parathermal, the diminishing elastic force of the springs with rise of temperature being compensated by a similar decrease of potential of the mercury column, which decrease depends upon the proportions given to the areas of the steel tube and its cup-like extensions. The instrument is suspended a short distance above its centre of gravity in a universal joint, in order to cause it to retain its vertical position, notwithstanding the motion of the vessel; the vertical oscillations of the mercury are almost entirely prevented by a local contraction of the mercury column to a very small orifice. The reading of the instrument is effected by means of electrical contact, which is established between the end of a micrometer-screw and the centre of the elastic diaphragm. The pitch of the screw and the divisions upon the rim are so proportioned that each division represents the diminution of gravity due to one fathom of depth. Variations in atmospheric pressure have no effect on the reading of the instrument, but corrections have to be made for latitude. The instrument has been actually tested in voyages across the Atlantic in the *Faraday*, and the comparisons with Sir W. Thompson's steel wire sounding apparatus showed it was very reliable.

The paper concluded with pointing out many ways in which the instrument might be of use; among others was that of indicating approaching danger if contour lines were first efficiently mapped.